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Improving the Implementation of Pavement Preservation Strategies in South Carolina

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IMPROVING THE IMPLEMENTATION OF PAVEMENT PRESERVATION
STRATEGIES IN SOUTH CAROLINA

A Thesis
Presented to
the Graduate School of
Clemson University

In Partial Fulfillment
of the Requirements for the Degree
Master of Science
Civil Engineering

by
Logan Reed
December 2015

Accepted by:
Dr. Jennifer Ogle, Committee Chair
Dr. Bradley Putman
Dr. Yongxi "Eric" Huang

ABSTRACT

With compounding budget constraints on infrastructure, cost effective solutions to maintain roadways are becoming increasingly important. Pavement preservation provides a cost effective option to keep the roadway network at an acceptable level. However, pavement preservation is a relatively new concept that many states have not fully implemented successfully.

This research supports efforts to improve the pavement preservation practices in the state of South Carolina. It analyzes the current pavement preservation practices in South Carolina as well as other states to identify where improvements could be made. The research also outlines a treatment tracking program for the state of South Carolina that will allow for more cost effective implementation of the preservation techniques. This study allows for a blueprint for the state to identify potential preservation candidates as well as tracking the effectiveness of the treatments used in the state.

DEDICATION

I would like to dedicate this thesis to my parents. I would not have been able to complete this work or my Masters without your support. Thank you for everything you have done for me.

ACKNOWLEDGMENTS

I would like to acknowledge Dr. Jennifer Ogle, Dr. Brad Putman, and Dr. Eric Huang for giving me the opportunity to complete my Masters. I appreciate how supportive and helpful you have been during my time as a Masters student at Clemson. I would also like to thank Todd Anderson and the South Carolina Department of Transportation for the opportunity to work on this project and the help provided on it.

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CHAPTER ONE

INTRODUCTION

Background of Study

Roadway pavement is a significant asset that must be maintained to achieve and extend the expected design life. Failure to perform pavement maintenance in a timely manner will result in accelerated damage and potentially premature need for rehabilitation and reconstruction projects. These types of projects are typically more expensive, time consuming, and disruptive to traffic than preventive maintenance activities. Pavement preservation provides a proactive alternative to pavement rehabilitation. The key to pavement preservation is to maintain the roadway network in good condition to prevent the need for the aforementioned rehabilitation and reconstruction projects. This practice aims to extend the pavement's service life which allows for better use of funds than continuously rehabilitating and replacing sections of roadway pavement. According to the Federal Highway Administration, every "dollar spent now on pavement preservation could save up to six dollars in the future" (2000). Keeping the entire roadway network at a higher level with use of fewer funds is possible through the use of pavement preservation.

Research Objectives

The South Carolina Department of Transportation faces the cost of maintaining and upgrading the roadway network in the state of South Carolina. Clemson researchers have undertaken a project to identify methods to improve the implementation of

pavement preservation strategies on asphalt concrete roadways in South Carolina. To accomplish this goal, several overarching objectives were identified:

1. Establish a system to determine when pavement preservation methods should be utilized and which method(s) is most appropriate for each application.
2. Identify “Best Practices” for pavement preservation programming and techniques that keep water out of the pavement, prevent oxidation of the asphalt, and maintain good skid resistance
3. Assess current pavement monitoring procedures to determine whether current monitoring procedures will support a formal preventative maintenance program and develop recommendations and training for any changes or improvements to the current procedure
4. Analyze different pavement preservation techniques in terms of performance (functional and safety), pavement life cycle (deterioration curve), and pavement life cycle cost.

For this thesis, a portion of the study described above was completed. This report will focus mostly on the first three objectives listed above. The detailed objectives of this research are:

1. Assess current SCDOT pavement preservation practices
2. Review existing pavement management software packages
3. Develop procedure to identify candidate pavement preservation sites of sufficient length to be addressed

4. Analyze candidate project locations based on district, county, route, and consecutive length
5. Define treatment tracking data items, data collection requirements, and reporting needs

To assess the above objectives, this thesis will provide a process to identify candidates for pavement preservation for SCDOT both in a data report and visually on a map. It will also give recommendations to how to track pavement preservation treatments to better implement them throughout the state.

Thesis Organization

This document includes chapters that will expand upon the various aspects of this study. Chapter 2 is a literature review that describes the current SCDOT pavement preservation practices as well as how current pavement management software products compare to the current SCDOT pavement management system. Chapter 3 provides a detailed description of the methods used in the study. The results of the study are provided in Chapter 4. Chapter 5 provides conclusions drawn from the results presented in Chapter 4.

CHAPTER TWO

LITERATURE REVIEW

The following literature review explores existing pavement management software packages, pavement preservation practices in other states, and the current pavement preservation practices in the state of South Carolina.

Existing Software Packages

To begin the project, existing pavement management software packages were analyzed to identify their data requirements and capabilities as well as suitability for use by the South Carolina Department of Transportation for pavement management. The three software packages reviewed were Streetsaver, PAVER 7.0, and OPTime. After completion of the analysis, a matrix was created to compare the three software packages to the current SCDOT ITMS. A matrix comparing the four systems can be found in Appendix A. A description of the three software packages as well as the SCDOT ITMS is given below.

Streetsaver

Streetsaver is a pavement management software published by the Metropolitan Transportation Commission. It is designed with pavement preservation principles in mind and is the most widely used PMS software on the West Coast (MTC, 2014). Streetsaver seems to be better suited for smaller networks such as those for cities or possibly small counties. Figure 2.1 below displays the inventory data input window for

Streetsaver. An inventory is created to identify the roadway section as well as describe the location, area, surface type, functional classification, construction dates.

The screenshot shows the 'Management Section Information' window in Streetsaver. The form is divided into several sections:

- Street Information:** Street ID: ARROWH, Section ID: 0100, Street Name: ARROWHEAD CT - ARROWH, # of Lanes: 2.
- Location and Dimensions:** Begin Location: END, End Location: FEATHER WY, Begin Point: 0.0000, End Point: 0.0000, Length (ft): 350.00, Width (ft): 33.00, Area (sq ft): 11550.00.
- Surface and Construction:** Surface Type: A - AC, Parking Lot Type: (empty), Slab Length: (empty), Slab Width: (empty), # of Slabs: (empty), Fund Source: U - Eligible for Outside Funding (FAU), Effective Date: (empty), Constructed: 01/01/1950, NHS: (checked).
- General and Area Information:** General Code: T - Truck/Bus Route, Originally Constructed: 01/01/1950, Culdesac: (checked), Exclude from Centerline: (unchecked), Area ID: 08 - District 8, Shoulder Width: (empty), Traffic Index: 4.0, ADT: (empty).
- Comments:** A large text area for user comments.
- User Selection:** A table with two columns: User ID and User Name. The table lists users from User6 to User10.

User ID	User Name
1734	User6
09	User7
4	User8
User4	User9
User5	User10

Figure 2.1: Inventory Data Input Window for Streetsaver

Streetsaver uses ASTM Standard D 6433 for condition assessment and offers full Paver distresses or MTC's 7-Distress (MTC, 2014). MTC's 7-Distress looks at seven distresses at three severity levels for pavement with asphalt concrete and surface treatments. These seven distresses are: alligator cracking, block cracking, distortions, longitudinal and transverse cracking, patching and utility cuts, rutting and depressions, and weathering and raveling. Figure 2.2 displays how inspection data is input into Streetsaver.

AC & Non-PCC Inspections

Drag a column header here to group by that column.

Street ID	Inspection Date	Inspection Number	No Distress	Special	Inspection Length	Inspection Area	Comments	Last Modified
BRANAN - 20	08/06/2015	1	<input type="checkbox"/>	<input type="checkbox"/>	100	3100		08/06/2015
CENTCR - 10	08/06/2015	1	<input type="checkbox"/>	<input type="checkbox"/>	100	3300		08/06/2015

Distress Type	Severity	Size	Last Modified
7 - Weathering & Raveling	H - High	2475	08/06/2015
6 - Rutting/Depression	L - Low	45	08/06/2015
4 - Long. & Trans. Cracking	M - Medium	33	08/06/2015

Street ID	Inspection Date	Inspection Number	No Distress	Special	Inspection Length	Inspection Area	Comments	Last Modified
CINABR - 10	08/06/2015	1	<input type="checkbox"/>	<input type="checkbox"/>	100	3200		08/06/2015
DENISE - 20	08/06/2015	1	<input type="checkbox"/>	<input type="checkbox"/>	100	3300		08/06/2015

PCC Inspections

Drag a column header here to group by that column.

Street ID	Inspection Date	Inspection Number	No Distress	Special	# of Slabs	Comments	Last Modified
CEDAR - 10	08/06/2015	1	<input type="checkbox"/>	<input type="checkbox"/>	20		08/06/2015
ELMST - 10	08/06/2015	1	<input type="checkbox"/>	<input type="checkbox"/>	20		08/06/2015
FOURTH - 10	08/06/2015	1	<input type="checkbox"/>	<input type="checkbox"/>	20		08/06/2015
CEDAR - 20	08/06/2015	1	<input type="checkbox"/>	<input type="checkbox"/>	20		08/06/2015

Distress Type	Severity	Size	Last Modified
4 - Linear Cracking	L - Low	13	08/06/2015
1 - Corner Break	M - Medium	10	08/06/2015
6 - Scaling/Map Cracking/Crazing	H - High	3	08/06/2015

[Preview PCI](#)
[Open](#)
[Close](#)

Figure 2.2: Inspection Data Input Window for Streetsaver

Streetsaver uses pavement condition index (PCI) to measure the condition of a pavement segment. The PCI has a scale of 0 to 100, with 100 being the best condition. This inspection data is used to calculate the PCI for the pavement section. The PCI is calculated for the current segment as well as projected for the future. It can be given for the segment or for the entire roadway network. .

Streetsaver also provides a GIS toolbox that can link street networks to a GIS base map. Streetsaver also provides a budget analysis feature. It can provide a budget needs calculation to estimate the amount of maintenance work needed to bring the condition of the network to a level that is the most cost effective to maintain. It can also calculate budget scenarios to determine the impact of different funding strategies and can develop

a list of pavement sections recommended for treatment within budget constraints specified by the user.

PAVER 7.0

PAVER 7.0, also known as MicroPAVER 7.0, is a maintenance and repair management tool that was developed by the U.S. Army Corps of Engineers and is distributed by the American Public Works Association (APWA). It is used to develop “cost effective maintenance and repair alternatives for roads and streets, parking lots, and airfields” (USACE, 2014). PAVER has the capability to create pavement network inventory and rate the pavement condition of this inventory. It also allows for development of pavement condition deterioration models, determining of present and future pavement condition, and determining maintenance and repair needs. Finally, it allows for analysis of different budget scenarios. PAVER 7.0 allows the user to create a maintenance and repair plan as well that will help with budgeting.

PAVER 7.0 gives the user the option to create a new inventory, import a PAVER database created previously (E60, E65, or E70 file), or import a network from GIS. These inventories include a network level, a branch level, and a section level. The networks are broken down into branches while the branches are broken down into sections. These classifications of levels allow the user to access pavement condition characteristics of different levels of the network. PAVER 7.0 allows for uploading, saving, and viewing images of roadway sections. The feature is called the EMSTM Image Viewer. This feature allows an image to be attached to the network, branch, or section it

is associated with in order to document the distresses found there. It also allows for multiple images to be stored for the same section in order to show the section over the time.

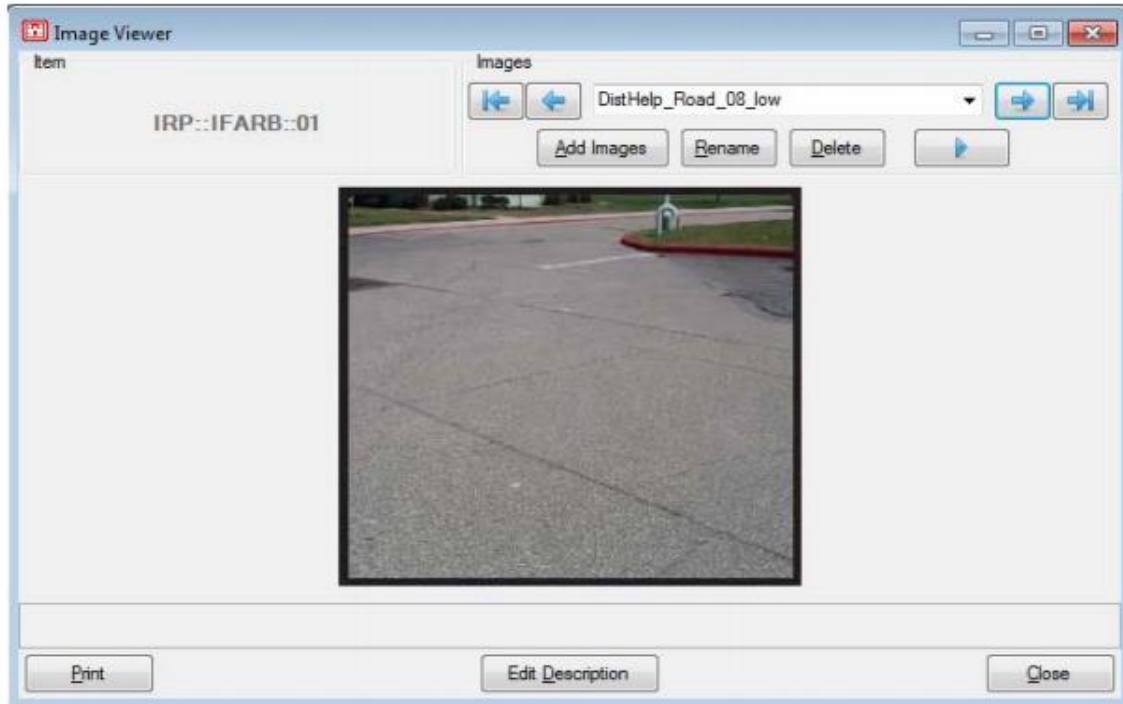


Figure 2.3: EMSTM Image Viewer in PAVER 7.0 (USACE, 2014)

PAVER 7.0 uses pavement condition index (PCI) to rate pavement condition. In order to calculate the PCI in the program, PAVAR 7.0 asks the user to define maintenance and repair (M&R) procedures and costs. The program asks the user to define Localized Stopgap M&R, Localized Preventive M&R, Global Preventive M&R, and Major M&R. For each of these types of maintenance and repair, the user classifies the work type, cost of work type, cost by condition of pavement, and consequence of each maintenance policy. In addition, PAVAR 7.0 asks the user to define priority based

on branch use and section rank. The user will also define codes and work units for all layer types used as well as the costs associated with each layer type.

PAVER 7.0 “must have an accurate account of the last construction date for each section, in order to accurately predict future pavement performance, maintenance requirements, cost, and inspection schedule” (USACE, 2014). For this reason, it is important for the user to input work history data. The work history data can be entered through GIS or tabular data similar to adding inventory or can be entered through the Work History Wizard shown in Figure 2.4 below.

Add Work Items and parameters

Add Work Item -- Project Level

Project: New

Total Project Area: 132742 SqRt

Work Category: Localized MR

Work Type: Patching - AC Shallow

Work Date: 8/16/2012

Material Type:

Thickness: 0.00 in

Select Item to Be Calculated

☐ Unit Cost: \$4.50 / SqRt

☒ Quantity: 0 SqRt

☐ Total Cost: \$0.00

Unit Cost From Table: \$4.50

<< Unit Cost <<

New Default AC&PCC_RD&RW

Comments:

OK Apply Cancel

Figure 2.4: Work History Wizard in PAVER 7.0 (USACE, 2014)

Entering inspection data is also an important component to the use of PAVER 7.0. The user must select the section being inspected first. The inspection entry window is shown in Figure 2.5 below.

Severity level

Distress codes

Information on Distresses

Quantity field

Distress summary for a sample unit

Small Image of Distress

DISTRES	Description	Severity	Quantity	Units	Density
1	ALLIGAT...	Low	179.22	SqFt	6.40
1	ALLIGAT...	Low	190.52	SqFt	6.80
1	ALLIGATO...	Medium	90.00	SqFt	3.21
4	BUMPS/S...	Low	3.00	Ft	0.11
7	EDGE CR...	Low	99.00	Ft	3.54
7	EDGE CR...	Medium	17.00	Ft	0.61
10	LONGITUL...	Low	27.00	Ft	0.96
10	LONGITUL...	Medium	59.00	Ft	2.11
10	LONGITUL...	High	116.00	Ft	4.14
11	PATCH/UT...	Low	26.00	SqFt	0.93

Figure 2.5: Inspection Entry Wizard in PAVER 7.0 (USACE, 2014)

PAVER 7.0 uses a “family modeling” system to group pavement sections together that have similar construction, traffic patterns, weather, and other pavement life effecting factors (USACE, 2014). This method of prediction allows PAVER 7.0 to give more accurate estimates of pavement life. PAVER 7.0 also offers a Condition Analysis tool that will show the condition of the pavement network based on inspection data, interpolated values between previous inspections, and family assignment based projected conditions (USACE, 2014).

PAVER 7.0 produces a number of reports for the user's benefit as well. It can produce GIS reports. Once the inventory has been assigned to GIS as a shapefile, PAVER 7.0 allows the user to view inventory based surface type, branch use, rank, or category. The user can also view the current or latest PCI values for each roadway section in GIS. Lastly, PAVER 7.0 allows the user to view PCI Deterioration, Stopgap M&R, Preventive M&R, Global M&R, and Major M&R Family Assignments in GIS. The GIS reports allow a visual report on the network roadway condition and its maintenance and repair. PAVER 7.0 produces summary charts that can compare any two attributes of the database. In addition, it can produce four standard reports:

- Branch Listing Report: A list of all branches and information on all branches
- Work History Report: Section by section report of all work completed in a section throughout its life
- Branch Condition Report: Shows average and weighted average condition of each branch
- Section Condition Report: Shows average and weighted average condition of each section

PAVER 7.0 also gives the option to display a section history report. This report displays the work and inspection history of the selected section.

OPTime

OPTime is a free analysis tool used “to enable pavement preservation engineers to analyze historical preventive maintenance-related performance and cost data in order to

determine the optimal timing of a given preventive maintenance treatment” (Hoerner et. al, 2004). The program gives the option of two types of analyses: detailed analysis and simple analysis. The detailed analysis analyzes observed data taken from monitoring the preventive maintenance treatment performances. The simple analysis gives states that have not implemented preventive maintenance treatments a chance to estimate performance of the treatments without actual performance data from the field. The software gives the option between two pavement types: HMA-Surfaced or PCC-Surfaced. This thesis is concerned only with the HMA-Surfaced options.

Condition Indicators	Units	Trend Over Time	Lower Benefit Cutoff Value	Upper Benefit Cutoff Value
<input checked="" type="checkbox"/> Composite index	0 to 100 scale	Decreasing	50	100
<input type="checkbox"/> Nonload-related cracking	Length of cracking, ft	Increasing		
<input type="checkbox"/> Load-related cracking	Length of cracking, ft	Increasing		
<input type="checkbox"/> Oxidation/raveling	Subjective scale (0 to 5)	Decreasing		
<input type="checkbox"/> Rutting	Avg rut depth, in	Increasing		
<input checked="" type="checkbox"/> Roughness/smoothness	IRI, in/mi	Increasing	0	140
<input type="checkbox"/> Friction	Friction number	Decreasing		
User Defined Condition Indicators				
<input type="checkbox"/> User defined 1	Index	Decreasing		
<input type="checkbox"/> User defined 2	Index	Decreasing		

Figure 2.6: Selection of Condition Indicator Screen in OPTime

(Hoerner et. al, 2004)

Once the surface type has been selected, the user must select condition indicators. HMA-Surfaced has seven default condition indicators with two user defined condition indicators. A description of these default condition indicators is shown in Table 2.1 below.

Table 2.1: HMA Condition Indicators Used in OPTime (Hoerner et. al, 2004)

Surface Type	Condition Indicator	Description
HMA	Composite index	Many agencies use composite indices to track pavement performance over time. Examples include a general cracking index or pavement condition index (PCI). Many of these decrease over time and are measured on scales such as a 0 to 100, 0 to 10, or 0 to 5.
	Nonload-related cracking	The sealing or rejuvenating nature of many surface treatments can reduce the development of environmental- or moisture-related cracking. This nonload-related cracking measure reflects that benefit, and would likely be measured in terms of the amount of cracking.
	Load-related cracking	Preventive maintenance treatments such as crack sealing and thin surface seals are effective at keeping the pavement structure free from moisture infiltration, thereby reducing load-related cracking associated with the weakening of the pavement structure. Therefore, the user may want to track the development of load-related cracking over time as a measure of the effectiveness of a particular preventive maintenance treatment. As with non-load-related cracking, load-related cracking would most likely be measured in terms of the amount of cracking.
	Oxidation/Raveling	The sealing or rejuvenating nature of many surface treatments can significantly reduce the occurrence of oxidation and raveling. Raveling is often reported as an area and severity level. Although there is not currently a widely accepted measure of oxidation, the user may want to consider the development of a subjective rating scale (e.g., a scale of 0 to 5).
	Rutting	Several preventive maintenance treatments may be used to correct rutting problems, so rutting may be used as a performance measure. Rutting is typically measured in terms of an average rut depth, which is expected to increase over time.
	Roughness/ Smoothness	<i>Roughness</i> typically increases over time and is often measured in terms of International Roughness Index (IRI). Some agencies prefer to characterize the measurement of surface characteristics in terms of <i>smoothness</i> instead of roughness. A smoothness measurement is typically expected to decrease over time (e.g., present serviceability index [PSI] is a subjective measurement on a 0 to 5 scale, where 5 represents a perfectly smooth pavement).
	Friction	Maintaining adequate surface friction is an important safety concern. Therefore, the effectiveness of a preventive maintenance treatment may be tracked in terms of its influence on friction. Friction is commonly measured in terms of a friction index or skid number (a characteristic that typically decreases over time).

Units, trend over time, lower benefit cutoff value, and upper benefit cutoff value must all be defined for each condition indicator used. The upper and lower benefit cutoff values

are set based on the goals of the agency. For a condition indicator that increases over time, the upper benefit cutoff value represents a failure condition level. With decreases over time, the lower benefit cutoff value represents the failure condition level. Once the condition indicators have been chosen, the software offers an option to choose a treatment from a list of default treatment types. The default treatment types for HMA-Surfaced Pavements are cracking filling/crack sealing, fog seal, slurry seal, scrub seal, microsurfacing, chip seal, thin overlay, and ultrathin friction course. There is also an option to add treatment types. After selecting the treatment, the user selects the treatment application ages to tell the program what years the program will analyze. The program also gives the option to include routine/reactive maintenance in the analysis. This maintenance can be added at a regular interval or at specific years. Figure 2.7 below shows the window in the program where the user goes through this process.

Optimal Timing of Preventive Maintenance Treatments - PM Treatment Selection

Preventive Maintenance Treatment Selection

Use these controls to setup your optimal timing experiment. In addition to selecting the treatment of interest, you may choose to include additional routine/reactive maintenance that is expected to affect the analysis.

PM Treatment Selection - HMA

Select the ONE treatment for which you would like to investigate "initial" application timing scenarios.

Slurry seal

Selected Treatment "Initial" Application Ages

Next, define the "initial" application ages that will be compared in the analysis. Note: ages may be entered as specific values (comma-separated) or age ranges (hyphen-separated) (see the example syntax below).

0,2,5

Example: An analysis of a treatment applied in years 3, 4, 5, 7, and 8 is entered as "3-5,7,8"

☒ Include routine/reactive maintenance (if selected, the costs will be included in the analysis)

Routine/Reactive Maintenance Program Definition

Use these controls to define a schedule of routine/reactive maintenance activities (i.e., although these activities do influence performance, their timing will not be optimized).

Application Method:

☒ Regular interval

☐ Specific years

Regular interval details

Application age range

Start Age	End Age
1	10

Set regular application interval

Apply maintenance every: 2 years

Figure 2.7: Treatment Selection Window in OPTime (Hoerner et. al, 2004)

SCDOT ITMS

South Carolina Department of Transportation currently has an Integrated Transportation Management Suite (ITMS) that allows users to run queries for roadway information, bridge information, sign inventory, daily maintenance work reports, traffic signal information, and pavement information. When querying for pavement information, the user has two options: query by clicking on the roadway on the map given or by launching the pavement viewer on the "Viewers" tab. Figure 2.8 below displays the pavement viewer in the SCDOT ITMS.

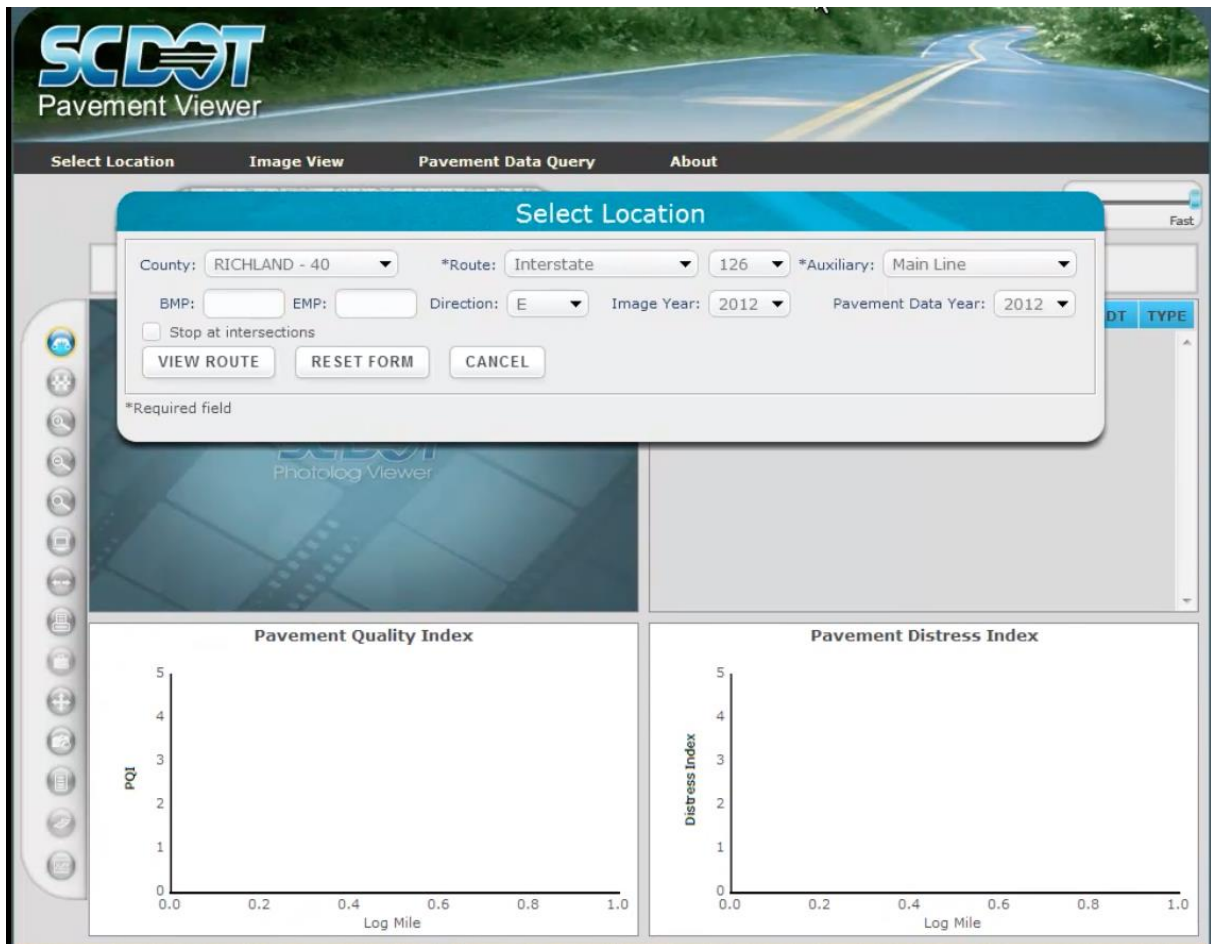


Figure 2.8: SCDOT ITMS Pavement Viewer Main Screen

On this main screen, the user has the ability to enter data to specify which route to view.

Once the user enters this information, the user can view the route in a screen similar to the one shown in Figure 2.9 below.



Figure 2.9: SCDOT ITMS Pavement Viewer Information Screen

This screen provides vital information on the pavement condition for the route. The screen also provides images taken at specific mile points. The screen portrays the rutting, pavement serviceability index (PSI), pavement distress index (PDI), pavement quality index (PQI), average annual daily traffic (AADT), and type of pavement for each section of the roadway broken up by beginning and ending mile points. An average of each category on the route as well as graphs for the PQI and PDI by beginning and ending mile points are also available. This screen provides the information necessary to identify segment candidates for pavement preservation.

In addition to the pavement viewer, the SCDOT ITMS allows users to see daily work reports (DWR). The DWRs can be seen in a report form or visually on the map.

Figure 2.10 below provides a view of the visual representation of DWRs.

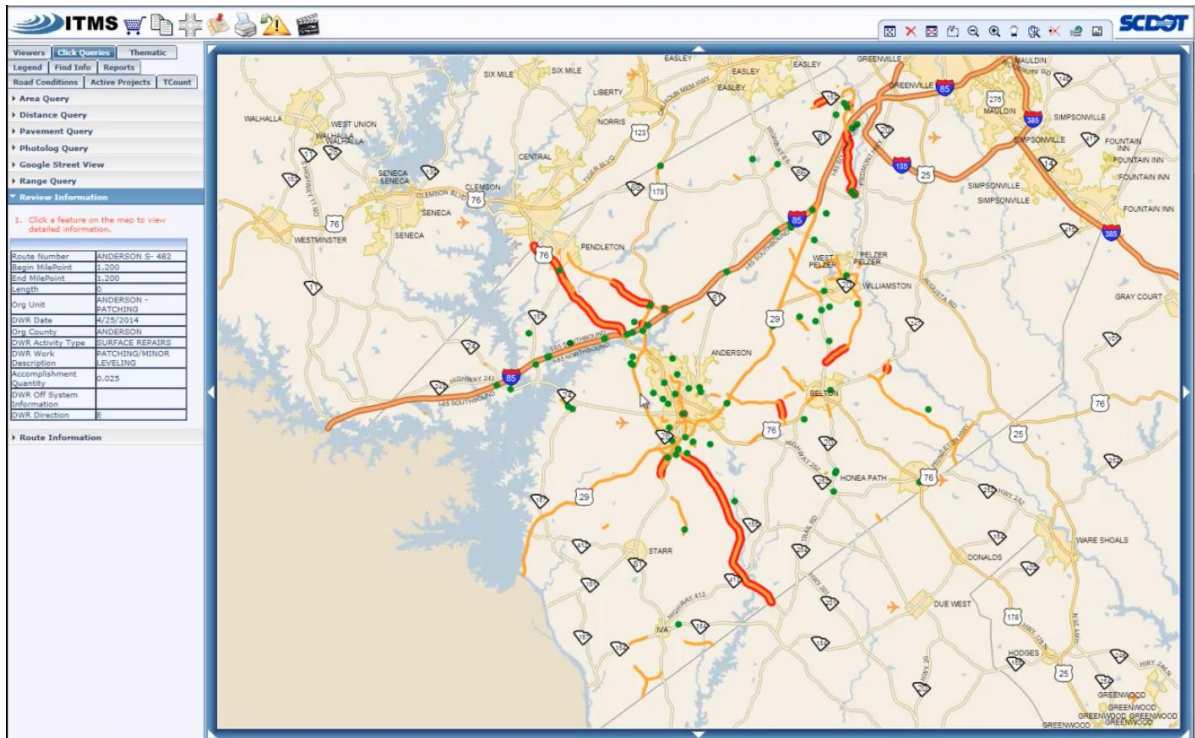


Figure 2.10: SCDOT ITMS DWR Report Visual

To query for specific reports, the user must specify the activity and work description from a drop down menu. In addition, the user will specify which county handled the maintenance work. The user must also specify the date range in which the maintenance activity occurred. The DWRs are provided in a standard report or a detailed report. The detailed report includes the project labor cost, equipment cost, material cost, and total cost in addition to the information given in the standard report.

Summary of Existing Software Packages

Each of the three existing pavement management software packages analyzed offer different options for pavement management. OPTime is by far the simplest program to use and provides a free management option. However, OPTime may not give the most accurate projection of how treatments will actually behave if historic data is not provided. The program does not require the input of data that could affect treatment selection and performance such as AADT, route type, and route location. Streetsaver is much more detailed than OPTime. It creates an inventory of roadways based on route information and has the ability to create a GIS version of the network. Streetsaver also allows much more detailed reports than OPTime by providing budget scenarios and projected condition of the pavement. The biggest drawback for Streetsaver is that it seems to be better suited for smaller networks such as those of cities and small counties because the cost of the program is driven by the number of segments maintained. PAVER 7.0 was the most detailed software analyzed. It allows for the development of the roadway inventory on three separate levels. It also provides a GIS toolbox, like Streetsaver, but it offers a chance to upload images to give a visual of distresses observed. PAVER 7.0 also provides the inputting of inspection data and keeping of detailed work history like Streetsaver.

The SCDOT ITMS provides detailed information on the current pavement condition. It does not, however, provide any information on pavement preservation candidates. The daily work reports and pavement viewer provide a foundation on which to build a pavement preservation section of the ITMS. The ITMS should use the existing

software packages as an example for developing models to predict future pavement condition, which treatments are most applicable, and the budget scenarios for the use of those treatments.

The SCDOT collects similar information in their daily work reports found in the ITMS as PAVER 7.0 collects in its work history reports. The PAVER 7.0 system has an input for work type, work category, work date, and cost. The SCDOT ITMS daily work report also allows for inputting information. The detailed DWRs also has cost breakdown in more detail than PAVER 7.0.

Other State Practices

Michigan

According to the MDOT *Project Scoping Manual*, MDOT is responsible for roads starting with “M”, “I”, or “US” in what is known as the “trunkline system” which includes 9,700 route miles (2015). MDOT uses the “Mix of Fixes” approach when selecting projects. This approach combines long term fixes, such as rehabilitation and reconstruction, with short-term fixes, like preventive maintenance techniques.

Michigan Department of Transportation established its Capital Preventive Maintenance (CPM) Program in 1992. Its purpose is “to protect the pavement structure, slow the rate of pavement deterioration and/or correct pavement surface deficiencies” (MDOT, 2010). The CPM program looks to prioritize newer pavement with preventive maintenance techniques. Preventive maintenance should be made until repair costs exceed the benefits of the techniques or the pavement structure requires reconstruction or

rehabilitation. Projects are selected with the help of the state's Pavement Management System (PMS). Recommended pavement condition levels are given for each preventive maintenance treatment based on Remaining Service Life (RSL), Distress Index (DI), International Roughness Index (IRI), Ride Quality Index (RQI), and Rut Depth in order to give a statewide consistency to choosing the most cost effective treatment (MDOT, 2010). Michigan uses the following treatments for flexible and composite pavement:

- Non-structural HMA Overlay
- Surface Milling with Non-structural HMA Overlay
- Chip Seals
- Paver Placed Surface Seal
- Micro-Surfacing
- Crack Treatment
- Overband Crack Filling
- HMA Shoulder Ribbons
- Ultra Thin Overlay

The *Capital Preventive Maintenance Manual* provides guidelines to choosing each treatment based on the minimum RSL, DI, RQI, IRI, and Rut Depth. The manual also outlines the life extension each treatment provides.

The Michigan Transportation Asset Management Council has published a guide for assessment management, *Asset Management Guide for Local Agencies in Michigan*, to help with the treatment selection for pavement and bridges. The first step in this guide is to assess current road conditions. The Council adopted the Pavement Surface

Evaluation and Rating (PASER) method to measure current pavement condition. PASER uses a visual survey to rate condition on a scale of 1-10 based on the pavement material and type of distress involved. The PASER method ratings are grouped into three categories: routine maintenance, capital preventive maintenance, and structural improvement. Routine maintenance includes PASER ratings 8, 9, and 10 and involves day-to-day activities that prevent water from seeping into the surface. Capital preventive maintenance involves PASER ratings 5, 6, and 7 and is used to “address pavement problems before the structural integrity of the pavement has been severely impacted” (TAMC, 2007). Structural improvement typically involves rehabilitation or reconstruction because the structural integrity of the pavement has been compromised and includes PASER ratings 1, 2, 3, and 4.

The Michigan Transportation Asset Management Council recommends the use of Mix of Fixes concept to find “the Right Fix, in the Right Place, at the Right Time” (TAMC, 2007). The Mix of Fixes approach looks at the remaining service life (RSL), Critical Distress Point (CDP), Extended Service Life (ESL), and risk and cost of deferring maintenance. The remaining service life is the time left before the pavement can no longer be benefited by capital preventive maintenance treatments. The critical distress point is where the pavement changes from capital preventive treatments to structural improvement. The extended service life is the time added to the RSL when a treatment is added. The risk and cost of deferring maintenance is the risk of not performing preventive treatments to good pavement.

The Michigan Transportation Asset Management Council has implemented a two-tiered training structure to help educate agencies. There is an introductory course on asset management and pavement management followed by advanced courses on pavement preservation and asset management (TAMC, 2007).

Virginia

Virginia Department of Transportation has designed decision matrices to determine maintenance needs for interstate, primary, and secondary route pavements. Maintenance activities for secondary pavements are classified into four different categories: Do Nothing (DN), Preventive Maintenance (PM), Corrective Maintenance (CM), or Restorative Maintenance (RM). Table 2.2 below breaks down the treatment types associated with each of these categories.

Table 2.2: Maintenance Activities for Secondary Pavements for Different Activity Category (Chowdhury, 2008)

Activity Category	Activities
Do Nothing (DN)	N/A
Preventive Maintenance (PM)	1. Minor Patching (<5% of Pavement Area) <ul style="list-style-type: none"> • Surface Treatment or Chip Seal Patching • Surface Patching (Depth 2")
	2. Crack Sealing
	3. Surface Treatment (Chip Seal, Slurry Seal, Latex, 'Novachip' etc.)*
Corrective Maintenance (CM)	1. Moderate Patching (<10% of pavement area; Partial Depth Patching; Depth 4")
	2. Partial Depth Patching (<10% of Pavement Area; Depth 2"-4") and Surface Treatment
	3. Partial Depth Patching (<10% of Pavement Area; Depth 2"-4") and Thin (1.5") AC Overlay
	4. 1.5" AC Overlay
	5. 1.5" Milling and 1.5" AC Overlay
Restorative Maintenance (RM)	1. Heavy Patching (<20% of Pavement Area; Full Depth Patching; Depth 8")
	2. ≤4" Milling and Replace with ≤4" AC Overlay
	3. Heavy Patching (<20% of Pavement Area; Full Depth Patching; Depth at least 6") and 1.5" AC Overlay
	4. Heavy Patching (<20% of Pavement Area; Full Depth Patching; Depth at least 6") and 4" AC Overlay

For Virginia, three condition indices are defined: Load-related Distress Rating (LDR), Non-load related Distress Rating (NDR), and Critical Condition Index (CCI). LDR gives an indication of the damage done to the pavement in the wheel path due to wheel loads (McGhee, 2002). New pavement is assigned an LDR of 100, and this index decreases as wheel path damage increases. The distresses that affect LDR include alligator cracking, patching, potholes, delaminations, and rutting (McGhee, 2002). NDR indicates the non-load related distress severity on the pavement such as block cracking,

patching and longitudinal cracking out of wheel path, transverse cracking, reflection cracking, and bleeding (McGhee, 2002). These distresses are not a direct consequence of wheel loads and usually can be treated with less drastic treatments (McGhee, 2002). NDR, similar to LDR, is indicated on a scale from 0 to 100, with 100 being new pavement. For both LDR and NDR, deduct values are calculated using modified PAVER curves developed by VDOT based on the distress types observed on the pavement (McGhee, 2002). CCI is the overall indicator of pavement condition and is defined as the lower value of LDR or NDR. CCI is used as one of the triggers for deciding on the maintenance treatment applied to the pavement section.

Maintenance treatment selection is using the CCI triggers as well as the decision matrices developed (Izeppi et. al, 2015). Figure 2.11 below shows the CCI triggers for each route type in Virginia.

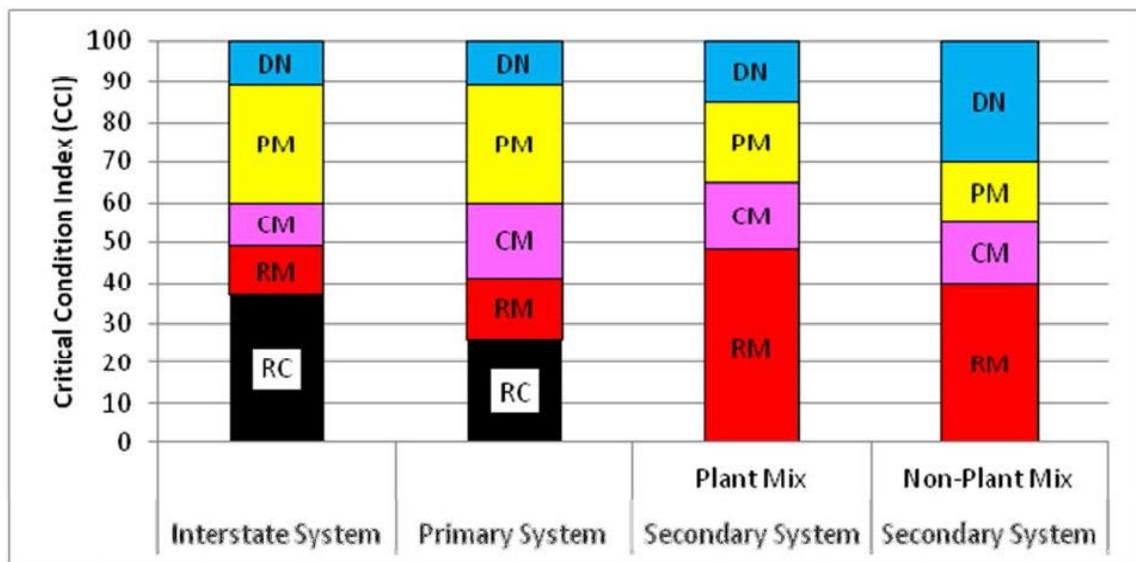


Figure 2.11: CCI Triggers for Each Maintenance Category (Izeppi et. al, 2015)

In addition to using the CCI triggers, VDOT uses a decision matrix that incorporates traffic level, structural condition, and maintenance history of the roadway segment.

California

The California Department of Transportation (Caltrans) has created the *Maintenance Technical Advisory Guide (MTAG) Volume I: Flexible Pavement Preservation Second Edition*. The first edition of this guide was developed in 2003 after Caltrans began a push to “provide technical and uniform guidelines to Caltrans personnel in their pavement maintenance and preservation activities” (MTAG, 2008). Caltrans also created the Pavement Preservation Task Group (PPTG) to get input on the most current practices from local agencies, the industry, and academia (MTAG, 2008). The second, and most recent, edition of the MTAG was published in 2008 to make sure the information provided in the guide was up to date with current technology and current information.

According to the MTAG, subgrade soil, pavement material characteristics, traffic loading, and environment all affect the performance of pavement. Subgrade soil must be classified correctly so it can be known how thick pavement should be on it.

The Caltrans treatment selection process begins by assessing the existing pavement conditions. The assessment involves three processes according to the MTAG:

- Visual site inspection and/or inspection of project information from database and/or records
- Testing the existing pavement

- Define the performance requirements for treatment

Caltrans uses the Caltrans Field Distress Manual or the Caltrans Pavement Survey to identify the pavement distresses and their severities. Caltrans recommends having the reviewer of the pavement fill out a well-developed pavement assessment form in order to create uniformity in the process (MTAG, 2008). Once the pavement condition is identified, Caltrans uses a treatment selection matrix to see feasibility of each treatment for the distress type. Figure 2.12 below shows the Caltrans Treatment Selection Matrix.

Preventive Treatments	Raveling	Oxidation	Bleeding	Rutting		Climate				Traffic Volumes			Night	Cold	Stop Points	Urban	Rural	High Snow Plow use	Treatment Costs				Add'l Premium for Short Work Periods or Work Zones \$/SQ YD		
				<1/2"	>1/2"	Desert	Valley	Coastal	Mountains	adt < 5000	adt>5000<30,000	adt >30,000													
Crack/Joint Seal																			Large Projects	Medium Projects	Small Projects	Work \$/SQ YD	Add'l Premium for night Work \$/SQ YD		
Emulsion Modified (Rubber)	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	8,000	0.50-0.65	0.60-0.75	0.70-0.85	+0.15-0.20	+0.60-1.00	
Seal Coats																			8,000	0.55-0.70	0.65-0.90	0.75-0.90	+0.15-0.20	+0.60-1.00	
Fog Seal (See note 1)	F	G	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	13,000	0.15-0.30	0.15-0.30	0.15-0.30	+0.05	+0.10	
Rejuvenator (See note 1)	G	G	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	15,000	0.20-0.50	0.20-0.50	0.20-0.50	+0.10	+0.20	
Seal Coat (See Note 4)	G	G	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	17,000	2.15	2.15	2.15	N/A	N/A	
Slurry Seals																									
Type II (See note 1)	F	G	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	23,000	1.60-2.20	1.75-2.40	1.90-2.60	N/A	+0.30	
Type III	G	G	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	24,000	1.60-2.20	1.75-2.40	1.90-2.60	N/A	+0.30	
REAS	G	G	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	24,000	1.20-1.80	1.20-1.80	1.20-1.80	N/A	+0.30	
Microsurfacing																									
Type II	G	G	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	31,000	2.00-2.80	2.10-2.90	2.25-3.00	+0.10-0.20	N/A	
Type III	G	G	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	31,000	2.00-2.80	2.10-2.80	2.25-3.00	+0.10-0.20	N/A	
Chip Seals																									
PWE - Med. Fine (See Note 4)	G	G	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	27,000	1.80-2.00	2.25-2.75	3.00-3.50	N/A	+0.50-1.00	
PWE - Medium (See Note 4)	G	G	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	F	27,000	1.80-2.00	2.25-2.75	3.00-3.50	N/A	+0.50-1.00
PMA - Medium (See Note 3.)	G	G	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	F	24,000	1.80-2.00	2.25-2.75	3.00-3.50	N/A	+0.50-1.00
PMA - Coarse (See Note 3.)	G	G	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	F	24,000	1.80-2.00	2.25-2.75	3.00-3.50	N/A	+0.50-1.00
AR - Medium	G	G	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	F	65,000	3.75-4.55	4.00-4.75	4.25-5.00	N/A	+0.50-1.00
AR - Coarse	G	G	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	F	65,000	3.75-4.55	4.00-4.75	4.25-5.00	N/A	+0.50-1.00
Cape Seals																									
Slurry	G	G	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N							
Micro	G	G	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N							
PM Alternative to a Seal Coat > 30,000 ADT																									
PBA-O	G	G	P	P	N	N	N	N	N	N	N	N	N	N	N	N	N	N	65,000	8-12	8-14	10-16		+120-4.00	
RAC-O	G	G	P	P	F	N	N	N	N	N	N	N	N	N	N	N	N	N	60,000	10-14	10-14			+150-3.50	
RAC-O High Binder (HB)	G	G	P	P	F	N	N	N	N	N	N	N	N	N	N	N	N	N	65,000	10-14	10-14			+150-3.50	
RAC-G	G	G	P	P	F	N	N	N	N	N	N	N	N	N	N	N	N	N	65,000	10-14	10-14			+150-3.50	
PBA-G	G	G	P	P	N	N	N	N	N	N	N	N	N	N	N	N	N	N	60,000	8-12	8-14	10-16		+120-4.00	
Thin Bonded Wearing Course (BWC)	G	G	P	P	F	N	N	N	N	N	N	N	N	N	N	N	N	N	85,000	10-14	10-14			+150-3.50	
Thin Bonded Wearing Course Rubber (BWC-RAC O/G)	G	G	P	P	F	N	N	N	N	N	N	N	N	N	N	N	N	N	85,000	10-14	10-14			+150-3.50	
Maintenance Treatments																									
Thin Lifts Overlays																									
Conventional	G	G	P	P	G	G	G	G	G	G	G	G	G	G	G	G	G	G	45,000	8-12	8-14	10-16		+120-4.00	
PBA	G	G	P	P	G	G	G	G	G	G	G	G	G	G	G	G	G	G	60,000	8-12	8-14	10-16		+120-4.00	
RAC	G	G	P	P	G	G	G	G	G	G	G	G	F	F	G	G	G	G	65,000	10-14	10-14			+150-3.50	

G-Good Performance
 Note: 1. Usually limited to shoulders, low volume roads and parking areas.
 Note: 2. Generally used on shoulders, parking areas and locations where less aggressive surface is desired.
 Note: 3. Under evaluation. Please consider other strategy at this time.
 Note: 4. Use of Pass Rejuvenating Seal Under evaluation. Please consider other PME strategy at this time.

Last revised 03/22/07

Figure 2.12: Caltrans Treatment Selection Matrix (MTAG, 2008)

Caltrans has a Pavement Preservation Program. This program includes the development of the aforementioned Pavement Preservation Task Group. It also includes the publishing of a Maintenance Technical Advisory Guide (MTAG) for flexible pavement and rigid pavement. These MTAGs also include training modules on each chapter to help with education. Caltrans puts on an annual California Pavement Preservation Conference. In these conferences, colleagues are able to present on their usage of different treatments as well as introduce new technology or research in the pavement preservation area.

Current South Carolina Practices

In 2009, the South Carolina Department of Transportation published *Guidelines for Selecting Preventive Maintenance Treatments for Asphalt Pavements*. This manual was published to help with selection of preventive maintenance treatments for flexible pavement preservation in South Carolina. This manual defines five preventive maintenance treatments used in South Carolina: crack sealing, chip seals, microsurfacing, ultra-thin asphalt overlays, and full depth patching. In addition, the manual describes asphalt distresses measured in South Carolina: fatigue cracking, transverse cracking, longitudinal cracking, raveling, rutting, bleeding, and oxidation. The descriptions of the preventive maintenance treatments and asphalt distresses seen below are taken directly from this manual.

South Carolina Pavement Distress Types

Fatigue Cracking

Fatigue cracking is a “series of interconnected cracks enclosing multi-sided pieces, usually less than one (1) foot on the longest side” (SCDOT, 2009). It results from repeated traffic loading or a weakening of the base layers of the pavement. It usually appears as a crack in the wheel paths. Low severity fatigue cracking may consist of:

1. A single crack in the wheel path
2. Disconnected hairline longitudinal cracks, longitudinal cracks
3. Longitudinal cracks with interconnections just beginning to form
4. Longitudinal cracks combined with horizontal cracks, forming a “net,” and commonly referred to as alligator cracking. The alligator cracking may involve all four wheel paths or even the entire road

Moderate severity fatigue cracking consists of at least three but usually all of the following:

1. Cracks that are not fine or narrow, but rather beginning to widen into widths of ½ inch or so
2. Cracking pattern has almost always reached the “alligator” stage
3. The pieces of the alligator cracking usually are beginning to separate and may be spalled as well
4. Often associated with old patches
5. The wheel path is often sunken where the moderate fatigue is concentrated

High severity fatigue cracking consists of at least three and usually all of the following:

1. Cracks that are noticeably wider, from $\frac{1}{2}$ inch to an inch or more
2. The cracking pattern has almost always reached “alligator” stage
3. The pieces of the alligator cracking usually are separate, spalled, and breaking up
4. Pieces of the pavement may have broken away entirely, creating holes in the alligator pattern.
5. Often associated with old patches
6. The wheel path is often sunken where the high fatigue is concentrated.

The SCDOT also defines the percentages for the extent of the fatigue cracking.

1. Fatigue in one Wheel Path = 3%
2. Fatigue in two Wheel Paths = 11%
3. Fatigue in three Wheel Paths = 22%
4. Fatigue in four Wheel Paths = 45%
5. Fatigue over entire area = 80%

Transverse Cracking

Transverse cracking occurs relatively perpendicular to the centerline of the pavement. It often occurs as a result of natural shrinkage caused by thermal cycling, high temperature susceptibility of the asphalt mix, or as a result of paving over jointed concrete with asphalt or bituminous mix. Transverse cracking is considered low severity if the cracks are less than $\frac{1}{4}$ inch in width and have little or no spalling associated with the crack. Moderate severity transverse cracking is identified with a crack of $\frac{1}{4}$ inch to $\frac{1}{2}$ inch in width with some possible spalling. Transverse cracking is considered high

severity if it is greater than ½ inch in width. The extent of transverse cracking is broken down as follows:

1. Transverse Cracks greater than 60 ft. apart = 5%
2. Transverse Cracks between 60 ft. and 30 ft. apart = 15%
3. Transverse Cracks between 30 ft. and 15 ft. apart = 25%
4. Transverse Cracks between 15 ft. and 5 ft. apart = 50%
5. Transverse Cracks less than 5 ft. apart = 99%

Longitudinal Cracking

Longitudinal cracking is cracking that runs relatively parallel to the centerline but is non-load associated, therefore is outside the wheel path. It can occur as a result of a poor construction joint, natural shrinkage, or the high temperature susceptibility of the asphalt mix. Longitudinal cracking usually occurs between the shoulder and the outside wheel path, between the wheel paths, or on or near the centerline. Low severity longitudinal cracking are less than ¼ inch in width with little or no spalling. Moderate severity longitudinal cracking is identified as between ¼ inch and ½ inch in width. High severity longitudinal cracking is greater than ½ inch in width with spalling often present and severe. The extent of longitudinal cracking is classified as follows:

1. One longitudinal crack = 20%
2. Two longitudinal cracks = 40%
3. Three longitudinal cracks = 60%
4. Four longitudinal cracks = 80%

5. More than four longitudinal cracks = 100%

Raveling

Raveling is the wearing away of pavement surface material by dislodging of aggregate particles and loss of asphalt binder. It affects the entire road. Low severity raveling involves the aggregate or binder wearing away but not to the point where binder pops out or the road becomes pitted. The roadway appearance may be grainy or like sandpaper. Moderate raveling involves aggregate and binder worn away causing a rough and pitted texture. The roadway is noticeably noisy and rough on the ride. High severity raveling involves a dramatic wearing away of aggregate and binder making the roadway very rough and pitted. The ride on the roadway is very noisy and very rough. The extent of raveling is defined as follows:

1. Very slight separation of aggregate from asphalt binder; surface still relatively smooth = 3%
2. Enough separation of aggregate and binder for road to become rough = 11%
3. Separation of aggregate and binder quite distinct and noticeably rough = 22%
4. Separation of aggregate and binder very marked; very rough = 45%
5. Separation of aggregate and binder dramatic; very rough = 80%

Rutting

Rutting is a longitudinal surface depression in the wheel path. Low severity rutting is defined as rut depth of less than ½ inch. Moderate rutting is defined as rut

depth of ½ inch to 1 inch. High severity rut depth is greater than 1 inch. Extent is not relevant for rutting because instruments measure the rut depth in wheel paths.

Bleeding

Bleeding is excess bituminous binder occurring on the pavement surface, usually found in the wheel paths. It does not have any severity levels because it can be monitored by its extent.

Oxidation

Oxidation is the hardening of asphalt binder due to exposure to oxygen in the air that occurs over time. It causes pavements to lose flexibility and crack easier.

South Carolina Preventive Maintenance Treatments

Crack Sealing

Crack sealing is a preventive maintenance treatment designed to keep water from entering cracks in the asphalt where it can weaken the base and subgrade of the pavement. According to the SCDOT Guidelines for Selecting Preventive Maintenance Treatments for Asphalt Pavements, “a good crack sealing candidate will have approximately three linear feet of sealable crack per square yard of pavement” (2009). Crack sealing is usually lower cost compared to other preventive maintenance treatments, but it has a relatively short life span. The manual recommends the treatment be done when the temperatures outside are cooler and cracks are relatively wide. Little

quantitative analysis has been performed to show the life extension provided by this treatment, however the estimated life expectancy of treatment is two to five years if the proper timing and treatment is used.

Chip Seals

Chip seals are layers of asphalt emulsion followed by a layer of aggregate. Double treatments involve two layers of chip seal with the first layer containing larger aggregate and higher rate of emulsion than the second layer. According to SCDOT Guidelines, chip seals “do a good job of stopping moisture infiltration and the oxidation that occurs to asphalt pavements from exposure to ultraviolet rays” (2009). The manual recommends that chip seals be used on roads with ADT of less than 1,500 vehicles per day, which puts them mostly on rural roads. The expected life of a chip seal ranges from five to seven years if the proper technique is used when implementing this treatment.

Microsurfacing

Microsurfacing involves a mixture of polymer modified asphalt emulsion, mineral aggregate, mineral filler, water, and other additives that are proportioned, mixed and spread using specialized equipment (SCDOT, 2009). Microsurfacing helps prevent oxidation, water infiltration, and damage to pavement due to ultraviolet rays. Microsurfacing has a life expectancy of approximately five to seven years. However, the SCDOT recommends not using microsurfacing on primary routes with high volume because the SCDOT has limited experience with microsurfacing.

Ultra Thin Asphalt Overlays

Ultra thin asphalt overlays are a hot-mix asphalt surface course applied in a lift between 0.75 to one inch thick. It can be placed with or without milling the existing pavement. Moderate or severe working cracks along with non-working cracks should be sealed at least six months in advance to placing ultra thin asphalt overlays. Ultra thin asphalt overlays should have life expectancy of six to eight years depending on how well the overlay bonds to the existing pavement.

Full Depth Asphalt Patch

Full depth asphalt patch is used to repair isolated areas of severe alligator cracking by removing and replacing failed base and sub-grade. It should include a minimum of six inches of asphalt surface course. The average life expectancy of full depth patching is about five years but depends on whether the entire area of failed base and subgrade were replaced properly.

South Carolina Candidate Selection

The South Carolina Department of Transportation received Highway Pavement Management Application (HPMA) index models developed by Stantec in April 2014.

The three performance indexes used are:

- Pavement Serviceability Index (PSI)
- Pavement Distress Index (PDI)
- Pavement Quality Index (PQI)

Pavement Serviceability Index (PSI)

Pavement Serviceability Index (PSI) is used to represent roughness in the SCDOT HPMA Index models. Roughness is usually measured in the field using devices that calculate the International Roughness Index (IRI) after measuring the longitudinal profile of the roadway (Stantec, 2014). IRI is converted into PSI for the SCDOT by the following equation:

$$PSI = 5 * e ^ {(-0.004*IRI)}$$

Where 5 is the index scale, 0.004 is the local calibration factor, and IRI is the International Roughness Index measured in inches/mile.

Pavement Distress Index (PDI)

Pavement Distress Index (PDI) is used to convert distress measurements into a composite distress index. Distress type, distress severity, and distress extent are important in finding the PDI of the pavement. SCDOT collects distress data in three severity levels (low, moderate, and high) for all bituminous (BIT) pavement distress types shown below except rutting, which is based only on extent and not severity level (Stantec 2014). The distresses are combined using a deduct value model which “is a modified version of the PCI Method (ASTM D 6433 Standard Practice for Roads and Parking Lots Pavement Condition Index Surveys)” (Stantec, 2014). This modified version has been customized to best suit the SCDOT. The equation for the deduct values is given below:

$$DV = 10 ^ {(a + b * \log_{10} (PDA))}$$

where DV is deduct value, PDA is percent distressed area (extent value), and a,b are model coefficients. Figure 2.13 below provides a display of the model coefficients (a,b) for each distress type for bituminous pavement.

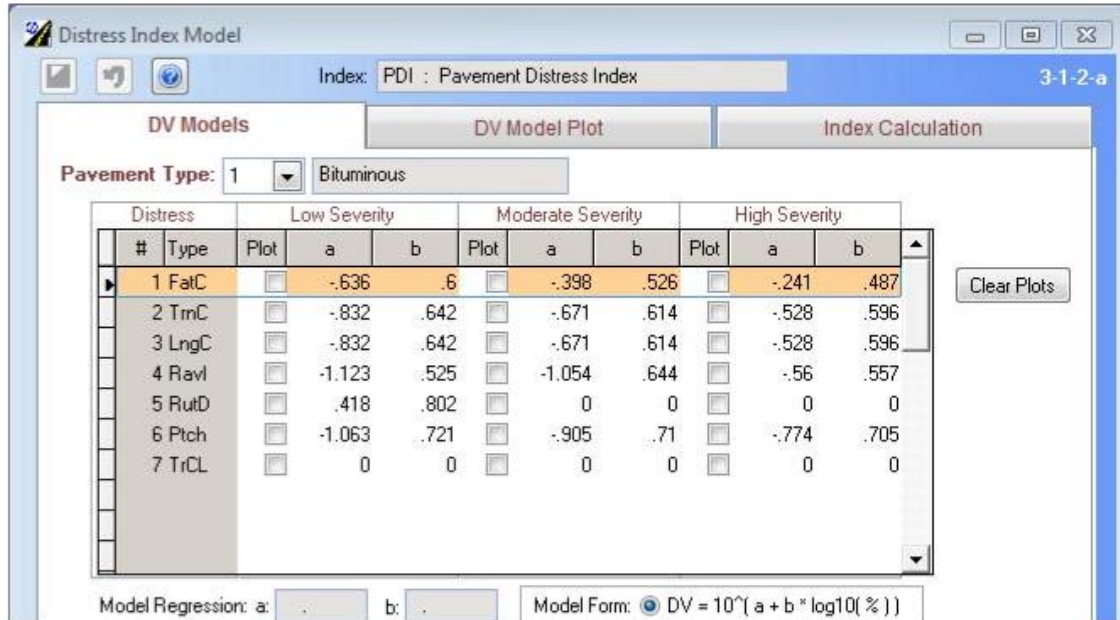


Figure 2.13: Model Coefficients for South Carolina HPM Index Models
(Stantec, 2014)

The deduct values (DV) are then summed to get the total. Equivalent Distress (ED) is then calculated for each distress as shown below:

$$ED = DV_i / DV_{\max}$$

The Number of Equivalent Distresses (NED) is then calculated by putting the sum of the deduct values (TDV) over DV_{\max} . Adjusted Deduct Value (ADV) is then calculated by the equation below:

$$ADV = 10^{(0.0014 - 0.3958 * \log_{10} (NED) + 0.9565 * \log_{10} (TDV))}$$

Finally, PDI is calculated by subtracting ADV from the index scale:

$$PDI = 5 - ADV$$

Pavement Quality Index (PQI)

Pavement Quality Index (PQI) is used to “provide a single overall assessment of the pavement quality” by combining PSI and PDI into an overall index. The equation for PQI is shown below:

$$PQI = PDI ^ 0.76 * PSI ^ 0.20$$

The SCDOT chooses pavement preservation candidates based on the PQI of the roadway section. The trigger values for pavement preservation for each road type in South Carolina are as follows:

- US and SC Routes: PQI greater than or equal to 3.2 but less than 4.0
- Federal-aid Secondary Routes: PQI greater than or equal to 3.2 but less than 4.0
- Secondary Routes: PQI greater than or equal to 3.0

These PQI triggers give SCDOT a set of candidates. Treatment selection in South Carolina is decided based on a number of other factors. According to the SCDOT *Guidelines for Selecting Preventive Maintenance Treatments for Asphalt Pavements*, the following factors are used for treatment selection:

- Traffic volumes
- Location
- Availability of Materials
- Cost effectiveness
- Volume of Work

Figure 2.14 below displays the treatment selection matrix created for the SCDOT.

Treatment	Distresses										Parameters					
	Raveling	Oxidation	Bleeding	Rutting		Cracking						Roughness		Traffic Vol.		
				< 1/2"	> 1/2" < 3/4"	Fatigue*		Long./Trans.				IRI < 170	IRI > 170	Low	Medium	High
						0 to 2% High	2 to 10% Medium	4 to 25% Low	0 to 2% High	> 2% Medium	> 4% Low					
Crack/Joint Seal																
Emulsion	NR	NR	NR	NR	NR	F	P	NR	NR	P	G	G	NR	G	G	G
Modified Rubber	NR	NR	NR	NR	NR	G	F	P	G	G	G	G	NR	G	G	G
Chip Seal																
PME - Lightweight Agg.	G	G	G	F	NR	F	F	F	F	F	F	G	NR	G		G
PME - Crushed Granite	G	G	G	F	NR	F	F	F	F	F	F	G	NR	G		G
Microsurfacing	G	G	G	G	F	F	F	F	F	F	F	G	NR	G	G	G
Ultra Thin Lift Asphalt Overlay	G	G	G	G	F	F	F	F	F	F	F	G	NR	G	G	G
Full Depth Patch	NR	NR	NR	NR	NR	G	G	G	NR	NR	NR	NR	NR	G	G	G
<div> <div>Good Performance</div> <div>Fair Performance</div> <div>Poor Performance</div> <div>Not Recommended</div> <div>Not Used</div> </div> <div> The quantity and/or severity that are listed for each distress indicate the degree that is considered significant. See Appendix A for a description of these distresses and severity levels. *Does not include isolated areas that can be repaired with a full depth patch. </div>																

Figure 2.14: Treatment Selection Matrix (SCDOT, 2009)

Comparison of SCDOT and Other States' Pavement Preservation Practices

Michigan has had a preventive maintenance program since 1992. It uses five different thresholds on which to base treatment selection. In addition, it is able to estimate the life extension each of these treatments will provide. While South Carolina does develop historic projections of treatment effectiveness, it does not have sufficient detail to standardize selection and the optimization of life extension expected from treatment. Michigan also focuses heavily on the remaining service life (RSL) and the critical distress point (CDP). Michigan wants to implement preservation techniques on roadways that are nearing the CDP to keep them from needing more serious maintenance

work. Finally Michigan has training courses offered to help educate agencies on how to best implement the preservation techniques.

Virginia uses a different set of condition indices from the other states reviewed. The critical condition index (CCI) is used as the trigger to choose what type of maintenance to perform on the roadway segment. Virginia then uses more detailed decision matrices based on traffic level, maintenance history, and structural condition of the roadway to decide on the best treatment type. South Carolina chooses treatments in a similar way. PQI in South Carolina is used as the original trigger before using the decision matrix shown in Figure 2.14 to better decide on the treatment type. However, Virginia boasts much more detailed matrices than South Carolina.

California treatment selection has become more uniform as they have introduced the MTAG as well as a manual and survey to identify pavement distresses. Caltrans has a very detailed treatment selection matrix shown in Figure 2.12. In addition, Caltrans holds an annual California Pavement Preservation Conference to encourage collaboration on this subject.

Distress data collected by each state seems to be similar. The distress types measured are similar. Michigan relies heavily on a number of indices used to make decisions on treatment types while South Carolina, California, and Virginia rely on treatment selection matrices. Virginia has detailed decision matrices to decide on type of treatment by using traffic and location. Virginia and California have much more detailed decision matrices than South Carolina. In addition, California does have a section on the treatment selection matrix related to climate. It is important for a large state like

California to take into account their climate, but this may also be important for South Carolina as the coastal areas have different climate than farther inland. South Carolina could benefit from a more detailed treatment selection matrix like the ones offered by California and Virginia.

CHAPTER THREE

METHODS

This thesis seeks to improve upon the current pavement preservation candidate selection process in the South Carolina Department of Transportation (SCDOT). To complete this goal, this research looked at current SCDOT practices through a pavement management survey. Next, this research drew from literature review to create a method to identify pavement preservation candidates from the current SCDOT data. This chapter gives a description of the survey and a description of the candidate selection methodology.

Pavement Management Survey

To get a better understanding of the current pavement preservation practices in the state of South Carolina, a survey was sent out to all the District Maintenance Engineers (DMEs), Resident Maintenance Engineers (RMEs), and Resident Construction Engineers (RCEs) in the state. This survey was created using the website SurveyMonkey, and it was distributed throughout the state by email. The survey was released originally in September of 2013. It was then released again in May of 2015. The survey questions are presented in Appendix B.

The survey consisted of nineteen questions. The first question three questions ask the respondent to provide contact information, position title, and years of experience with pavement maintenance and preservation the individual has. Question 4 is an open-ended question that asks the respondent to briefly explain the process used to identify

preservation candidates in their area. Question 5 asks if the respondent's area conducts pavement evaluations to supplement the data collected by the van. If yes, the next question asks if there is a written process for these evaluations. Next, the respondent is asked if they maintain a separate database. The next two questions ask the respondent to answer the frequency of these evaluations as well as the coverage of these evaluations. The survey then asks the respondent to choose the pavement preservation techniques that are used in their area from a list given. There is also a chance for the respondent to put in their own techniques if they are not on the list. The respondent is then asked three open-ended questions regarding decisions on which preservation treatment to use as well as the types of techniques they prefer to use and prefer not to use. They were also asked why they would choose to use certain techniques and why they would not use others. Question 14 asks if there are any differences in treatment decisions by county in their district. The next question asked if there was a specific pot of funds for maintenance specifically for pavement preservation in the respondent's area. The survey then asks for a description of the typical funding level and funding distribution from district to county. Two of the last three questions ask about the obstacles that pavement preservation faces and suggestions that the respondent might have for improving pavement preservation decisions, policies, or procedures. Question 18 asked the respondent if they would rather have a stand-alone software package for pavement preservation or have that system added to the SCDOT RIMS/ITMS data system.

Identification of Preservation Candidates

Identifying pavement preservation candidates in the state is the first major step in implementing pavement preservation effectively. South Carolina uses pavement quality index (PQI) to identify those roadway segments that qualify for pavement preservation techniques. For the SCDOT, different route types have different trigger values. These trigger values are shown below in Table 3.1.

Table 3.1: SCDOT Preservation Candidate Trigger Values

System	PQI Trigger Values
US and SC Routes	$PQI \geq 3.2 < 4.0$
Federal-aid Secondary Routes	$PQI \geq 3.2 < 4.0$
Secondary Routes	$PQI \geq 3.0$

For this research, two analyses were performed to identify preservation candidates. The first analysis identified segments that were 100% consecutive while the second analysis identified 80% consecutive segments to identify how many more segments would be eligible if one out of the five consecutive necessary consecutive segments did not meet the PQI criteria. The methodology for identifying preservation candidates in this research is given in the steps below.

Step 1: Review SCDOT Data and Identify Important Criteria

For this analysis, pavement preservation candidates were identified for non-federal aid eligible secondary route roadway segments found in a Microsoft Excel worksheet given by the SCDOT. Based on the route type, the analysis looked for segments that had a PQI greater than or equal to 3.0. This analysis used the Predicted PQI given in the 2014 SCDOT data. The analysis also sought out consecutive segments

of at least 0.5 miles in length to make it economical to implement pavement preservation techniques. Each line in the Microsoft Excel worksheet represented a single roadway segment. The roadway segments are identified by the county in which they are located using a county code. They were also identified by route type of secondary (S-). Next, the segment had a route number associated with it as well as a direction (N, S, E, or W). Usually these segments were 0.1 miles in length, with the only exceptions being the last segments along a roadway that were less than 0.1 miles in length. As a result, roadway sections were identified as candidates if five or more consecutive segments met the threshold value – thus establishing a minimum length of 0.5 mile. The Microsoft Excel worksheet provided by the SCDOT had each roadway segment in order according to its beginning and ending mile point along the roadway. To identify consecutive segments, segments must have the same county code, route type, route number, and direction.

Step 2: Creation of 100% Consecutive Segment Code

The next step in pavement preservation candidate identification was the creation of a code that could identify the candidates from the data. The code was created by using MATLAB to scan the Microsoft Excel worksheet for candidates. As stated above, the code needed to identify roadway segments with identical county codes, route type, route number, and direction. The segments were already sorted in consecutive order by beginning and ending mile points, so the code was able to read down the document without further sorting.

The MATLAB code first looks at Column N in the Microsoft Excel worksheet to see if the predicted PQI for 2014 is greater than or equal to 3.0. If the predicted PQI is

less than 3.0, the code will indicate “FALSE” in a new column it creates at the end of worksheet. If the predicted PQI meets the criteria, the code then moves on to check if five or more segments meeting the predicted PQI criteria are consecutive. To check if the segments are consecutive, the code first checks Column A to see if the county codes for the segments is the same. Next, the code checks Column B to compare the route types of the segments. Then, the code checks Column C to see if the segments have the same route number. Finally, the code looks at Column E to make sure the segments have the same direction. If five or more consecutive rows of segments meet all of these criteria, the code indicates “TRUE” in the newly created column at the end of the worksheet for every segment involved. If all these criteria are not met, the code writes “FALSE” in that column.

Step 3: Extracting Candidates from Original Worksheet

After the code determines whether each segment was “TRUE” or “FALSE”, the next step was to separate candidates from non-candidates. To separate these candidates, the Microsoft Excel filter feature was utilized. Using Advanced Filter, the segments with “TRUE” in the last column of the spreadsheet were moved to a new blank spreadsheet. Using the same tool, segments with “FALSE” in the last column were also moved to their own separate spreadsheet.

Step 4: Mapping Candidates in GIS

After the candidates were identified, the final step was to import the data into ArcGIS to get a visual representation of the candidates. To accomplish this step, the Microsoft Excel spreadsheet with the candidates had to be converted to a text file.

However, due to route types and numbers being repeated in each county, it was necessary to use a tool to separate Microsoft Excel spreadsheet into multiple text files based on the county code. By extracting based on county code, the candidates were separated into 46 text files, one for each county.

In ArcGIS, the shapefile for the South Carolina counties was added. Next, the secondary routes shapefile for the state of South Carolina was created by using Select by Attributes on the shapefile containing all roadways in South Carolina and selecting according to route type (S-). Then this selection was exported as its own shapefile for Secondary Routes. Next, a selection was made in the Secondary Routes shapefile for each county code. These selections were then exported to create a shapefile of secondary routes in each county. Next, each text file for each county was added to the map. A route shapefile was generated for each county's candidates by querying the candidates based on route number and beginning and end point in each county. After creating shapefiles for each separate county's candidates, the candidates were joined into one shapefile for the entire state of South Carolina by selecting all and exporting them as their own shapefile. The process was repeated to include the non-candidates into the map.

Step 5: 80% Consecutive Segment Identification

After completing the analysis for segments that are 100% consecutive, an analysis was performed to see how the number of pavement preservation candidates would change if the analysis included roadway segments that were 80% consecutive. To complete this analysis, the original MATLAB code was edited. The code can be seen in Appendix D. This code searched for segments that were 80% consecutive with the criteria that at least

four out of five consecutive segments that met the PQI requirements. This means that even if only one out of five consecutive segments did not meet the PQI requirements, all of those segments were still labeled as candidates with a “TRUE” written in the new column, including the segment that did not meet the PQI criteria. The results of this analysis were then added to ArcGIS through the same procedure described for the 100% consecutive candidates.

Step 6: Comparative Analysis of 80% and 100% Consecutive Segments

After identifying the 100% consecutive segments and 80% consecutive segments, there was an analysis performed to compare the two datasets. The two analyses were performed to find the number of segments left out because one segment in group did not meet the PQI requirement.

Treatment Tracking Program

Defining treatment tracking data items was another major objective of this research. The first step in defining these data elements was to analyze and define the data already collected by the South Carolina Department of Transportation. As shown in Chapter 2, the SCDOT ITMS has a section where pavement quality data can be accessed. Looking at a tutorial for this section of the ITMS, it was noted what information the SCDOT allows users to view now. Microsoft Excel worksheets were also received from the SCDOT that showed an example of the type of data collected. After noting the current SCDOT data elements, the existing software packages’ data elements were also analyzed. After comparing the data needed by all these programs, a data matrix, shown

in Appendix E, was created to provide SCDOT with data that should be included in an ITMS treatment tracking program.

CHAPTER FOUR

RESULTS

Pavement Management Survey

Survey Results

The Pavement Management Survey distributed to the South Carolina Department of Transportation provided 98 total responses. The respondents included 10 District Maintenance Engineers (DME), 40 Resident Maintenance Engineers (RME), and 29 Resident Construction Engineers (RCE). Responses came from 3 Assistant RMEs, 2 Assistant RCEs, and 4 Assistant DMEs as well. The Contracts Engineer for District 3 and 7 also responded.

When asked about their years of experience with pavement maintenance and preservation, the responses were distributed as shown in Figure 4.1 below.

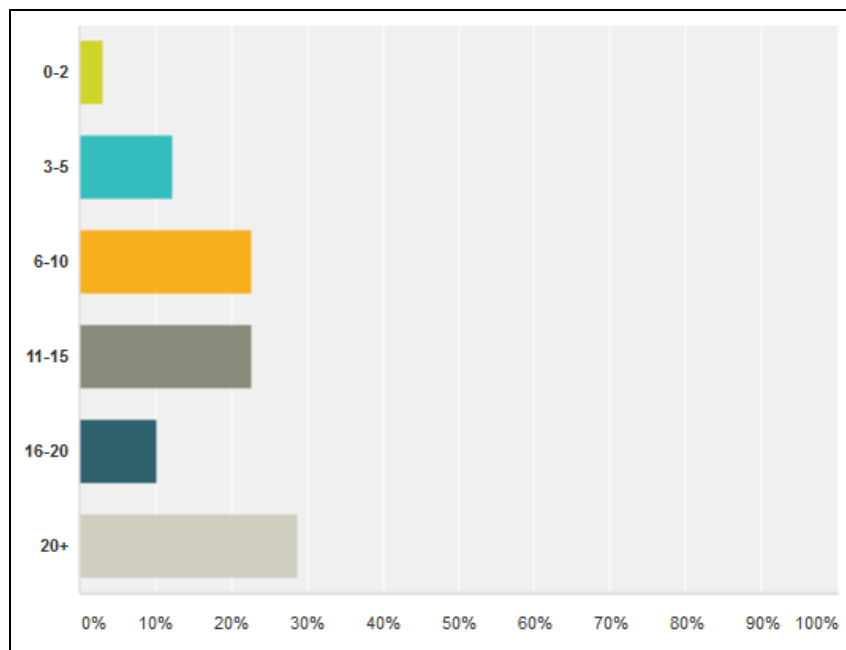


Figure 4.1: Years of Experience with Pavement Preservation

Seventy percent of the DMEs (7) had 20+ years of experience. One DME had 16-20 years of experience. Two of them had 6-10 years of experience. The RMEs had a wide range when it came to years of experience. They all had at least 3 years of experience and over half of them had at least 11 years of experience. The RCEs also had differing years of experience with most of them having between 6 and 15 years of experience.

The respondents were then asked what process they use to identify preservation candidates in their area. Most DMEs reported that the process used to identify preservation candidates in their areas involved using the SCDOT ITMS data system and performing visual inspections in the field. Some reported the use of a state and district ranking system as well as reports from district offices. The RMEs that answered the survey had a variety of answers to how they identify preservation candidates. However, almost all of the respondents stated they used some combination of district reports, querying the SCDOT data, and field inspections to identify candidates. Some used a personal list of candidates or a plan created for a specific area to help prioritize candidates. The majority of the RCEs that took the survey either did not know how the preservation candidates were identified or stated that the RME or maintenance area chose the candidates. Some others stated they were chosen based off district office reports.

When the respondents were asked if their area conducts pavement evaluations to supplement the data collected by the van, 28 (29.79%) said there are not supplemental evaluations. Thirty five (37.23%) stated that their area did conduct these supplemental pavement evaluations while 31 (32.98%) of them stated that their area did these supplemental evaluations sometimes. Five of the DMEs said their areas did perform the

pavement evaluations while 4 of them said their areas did not. Nine RMEs reported that they did not perform the pavement evaluations and 14 said their area did perform the supplemental evaluations with 17 doing it sometimes. The RCEs that took the survey had 9 state their area performed the supplemental evaluations and 12 state their area did not perform the supplemental evaluations. Seven RCEs reported that their area sometimes did evaluations to supplement the data collected by the van.

Over 75% (46) of the respondents stated that they did not have a written process for these evaluations. Five out of the six DMEs that answered said they have no written process for the evaluations. Twenty-six out of the thirty RMEs that responded said there was no written process. Over half of the RCEs that answered said there was no written process.

Only 18 out of 57 respondents stated that they did maintain a separate database for these evaluations. A few respondents were unsure if a separate database existed or not. Two respondents stated that there was a Microsoft Excel worksheet that showed work done in their area. When asked about the frequency of the evaluations, five DMEs answered this question. Four of them stated it was done annually with the other one stating they were done as needed. One DME stated that Act 114 discontinued the practice of these evaluations. Twenty-nine RMEs answered this question. Fifteen RMEs said the evaluations were done annually. Five RMEs said the evaluations were done as needed. The rest of the RMEs said the frequency could be daily or vary. Most of the RCEs are not sure about the frequency of evaluations. The coverage of the evaluations also differed. Three DMEs answered this question. One said approximately 100 miles per year while

another said 6000 miles. The other DME stated that these were done as needed due to upcoming contracts. Eight RMEs said the route category determined the coverage. Others gave certain numbers for miles per year. Over half of the RCEs were not sure about this question.

The survey then asked for the types of pavement preservation treatments used in each respondent's area. Figure 4.2 below shows the responses to this question. Clearly, chip seals, full depth patch, and crack sealing are the three most used treatments in South Carolina.

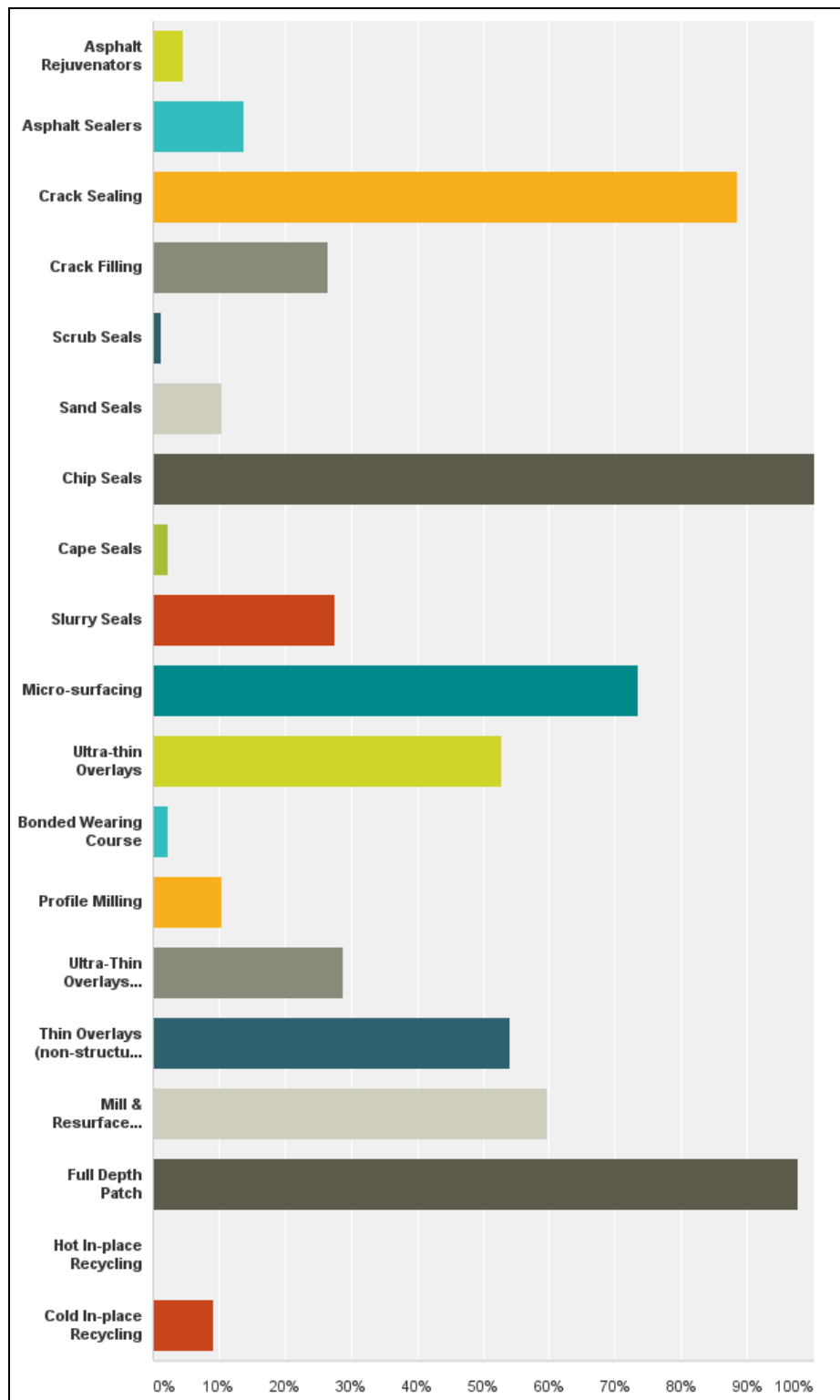


Figure 4.2: Types of Treatments Used in South Carolina

Next, respondents answered how they decide which preservation treatment to use for a roadway. Nine of ten DMEs answered this question. Five of them stated that they use the condition of the pavement and its characteristics. Two of them stated that the RCE made the recommendations. DMEs also stated that they use past experience when choosing the treatment type. Most of the RMEs stated that the treatments are chosen based on roadway condition, ADT, and location of the road. Three said the district office makes the decision. The majority of RCEs stated the contract dictated what type of treatment to use.

When asked if there was a specific treatment that was preferred, five of the nine DMEs did not have a specific treatment that they would prefer to use. The DMEs that had preferences stated that they wanted the cheapest and most effective treatments. Eleven RMEs stated that there was no preference on a specific type. Fourteen RMEs stated they preferred chip seals with a couple saying that they are cost effective. RCEs prefer to use thin lift overlays, full depth patching, and mill and resurface.

The survey also asked if there were treatments that the respondents would rather not use. Four of seven DMEs did not have a specific treatment that they preferred not to use. Two DMEs would rather not use thin lifts. Fifteen RMEs did not have treatments they would rather not use. A few others preferred not to use slurry seals, especially in large volume areas. RCEs don't like to use microsurfacing or slurry seals.

Sixty percent of DMEs (6) said there were no differences in treatment by county in their districts. Sixty one percent of the RMEs did not know with only 6% answering there were differences. Seventy two percent of the RCEs do not know if there are differences.

Sixty percent (6) DMEs stated they do have specific pots of money for maintenance. Forty-six percent of RMEs stated that a specific pot of funds is available sometimes. Forty percent of RMEs said specific pots for maintenance do exist. Fifty-two percent of the RCEs said there was a specific pot while 26% said there was sometimes. When asked about typical funding level, most of the DMEs stated that the district office distributes the funding. These allotments come as Federal Aid or Non-federal Aid. Nine RMEs stated that the district distributes the money. Eight stated that the money is split by county based on the size of the county and the total length of roadway in the county. Seven RMEs did not know about the funding. Most of the RCEs don't know the typical funding level.

All 8 DMEs that answered this question stated that funding was one of the main obstacles. One DME stated that public perception of pavement preservation and having the roadways in good enough shape for effective pavement preservation techniques were also important obstacles. Seventeen RMEs stated funding was the biggest obstacle faced. Six other RMEs stated that the roads were not in good enough condition to preserve. Two other RMEs stated that public perception was an obstacle.

When asked whether a pavement preservation support system should be stand alone or added to the SCDOT data system, the majority of respondents wanted it to be added to the SCDOT data system. Figure 4.3 below portrays the overall results given by the survey for this question. Two DMEs wanted a stand-alone system while 5 wanted it to be added to the SCDOT data system. One DME said either method would be fine. Fifteen RMEs (43%) want a stand-alone system while 20 RMEs want it to be added to

SCDOT system. Sixty three percent of the RCEs wanted it to reside in the SCDOT system.

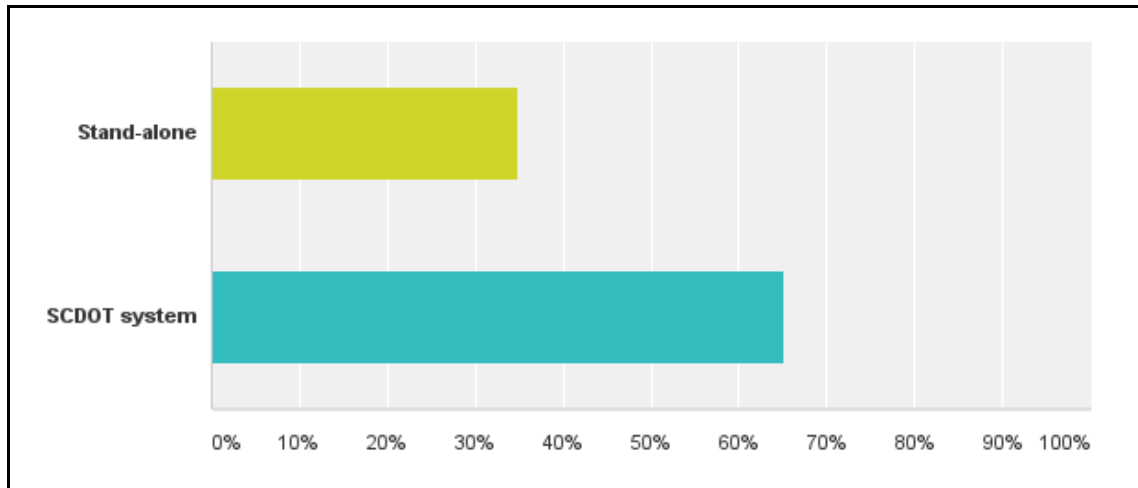


Figure 4.3: Results for Stand-Alone or Integrated SCDOT System

The last question on the survey asked respondents for suggestions for improving pavement preservation procedures, decisions, and policies. Multiple respondents claimed increased funding is desperately needed. Others stated that South Carolina needs to broaden the techniques it uses in order to become more cost effective. One respondent suggested implementing a public awareness program to educate the public on what is actually occurring in pavement preservation. Multiple others suggested that there be additional training as well as local input or checklist implementation when developing a statewide program.

Summary of Survey Results

The pavement management survey distributed to the SCDOT provided a good look into the current pavement preservation practices used in South Carolina. The

evidence from the survey showed that currently the SCDOT has little in the way of uniform procedures for implementing pavement preservation. The majority of people who took the survey also wanted a pavement preservation decision support system that could be added to the current SCDOT ITMS. From this information, this research team attempted to define a data analysis process that could be added to the current SCDOT ITMS. The survey also pointed out the one glaring problem with pavement maintenance: funding. There was overwhelming evidence that the largest problem with pavement maintenance and preservation is the lack of funding to complete the necessary projects. Support was also suggested for a public education program.

Candidate Selections

100% Consecutive Segment Preservation Candidates

For 100% consecutive segment analysis, 30,615 segments met the qualifications. These segments represented 3,006 miles of secondary roadway. In contrast, 189,232 secondary roadway segments, representing 17,613 miles, did not qualify for pavement preservation. Only approximately 14% of secondary non-federal aid eligible roadway segments qualified for pavement preservation treatments. These qualifying segments had an average PQI of 3.60. Table 4.1 below portrays the candidate breakdown for each county in the state of South Carolina.

Table 4.1: Candidates by County (100% Consecutive)

County Name	Number of Candidate Segments (100% Consecutive)	Length for Candidate Segments (100% Consecutive) (miles)	Average Predicted PQI for Candidate Segments (100% Consecutive)	Non-Candidate Segments (100% Consecutive)	Non-Candidate Segment Length (100% Consecutive) (miles)	Non-Candidate Average Predicted PQI (100% Consecutive)
Abbeville	414	40.84	3.50	3124	295.944	2.54
Aiken	1827	176.785	3.56	6258	566.413	2.42
Allendale	660	65.479	3.47	2369	223.657	2.24
Anderson	1045	102.857	3.82	3809	352.149	2.35
Bamberg	533	52.45	3.52	2562	241.74	2.07
Barnwell	313	30.33	3.69	2811	258.18	2.51
Beaufort	337	33.08	3.32	2516	227.84	2.17
Berkeley	511	49.927	3.68	5236	483.6	2.23
Calhoun	504	49.49	4.00	2572	246.16	2.21
Charleston	563	55.33	3.66	6376	564.154	2.16
Cherokee	515	50.57	3.47	3867	367.414	2.43
Chester	295	28.82	3.70	4877	458.49	2.24
Chesterfield	972	95.99	3.45	4846	455.19	1.91
Clarendon	1114	109.93	3.68	3126	291.91	2.50
Colleton	897	88.63	3.54	5224	495.31	2.42
Darlington	1304	127.93	3.48	4644	424.49	2.40
Dillon	331	32.74	3.48	4060	384.7	2.36
Dorchester	469	46.26	3.42	3271	304.28	2.09
Edgefield	501	48.85	3.89	2658	250.93	2.35
Fairfield	342	33.77	3.42	3140	299.52	2.30
Florence	1302	128.3	3.43	6002	552.25	2.45
Georgetown	557	54.46	3.50	3032	278.79	2.10
Greenville	562	55.31	3.56	4591	430.168	2.25
Greenwood	476	46.62	3.88	2977	276.88	2.42
Hampton	663	64.47	3.61	2763	258.59	2.43
Horry	748	73.61	3.70	4963	464.239	2.25
Jasper	108	10.59	3.46	2326	220.41	2.31
Kershaw	487	47.78	3.75	5599	529.76	2.16
Lancaster	242	23.65	3.84	3985	371.97	1.83
Laurens	812	79.24	3.76	4510	420.85	2.41
Lee	462	45.79	3.44	2417	226.68	2.03
Lexington	1539	151.428	3.43	6854	626.744	2.50
Marion	580	56.97	3.68	2376	224.24	2.11
Marlboro	192	18.94	3.63	2886	263.894	2.42
McCormick	548	54.04	3.82	4178	396.02	1.55
Newberry	292	28.23	3.97	4118	386.65	2.27
Oconee	480	47.12	3.42	3708	351.947	2.35
Orangeburg	1924	189.05	3.48	7439	690.447	2.28
Pickens	482	47.53	3.67	2050	195.6	2.46
Richland	819	79.421	3.78	8329	748.438	2.30
Saluda	369	36.43	3.90	3231	308.1	2.23
Spartanburg	404	39.8	3.49	4744	447.729	2.18
Sumter	863	84.79	3.51	5070	463.85	2.19
Union	294	28.85	3.89	2984	282.2	2.48
Williamsburg	889	87.13	3.55	4691	446.54	1.77
York	1074	105.45	3.68	6063	557.582	2.35
TOTAL	30615	3005.057	3.60	189232	17612.639	2.26

Figure 4.4 below displays the pavement preservation candidates throughout the state of South Carolina.

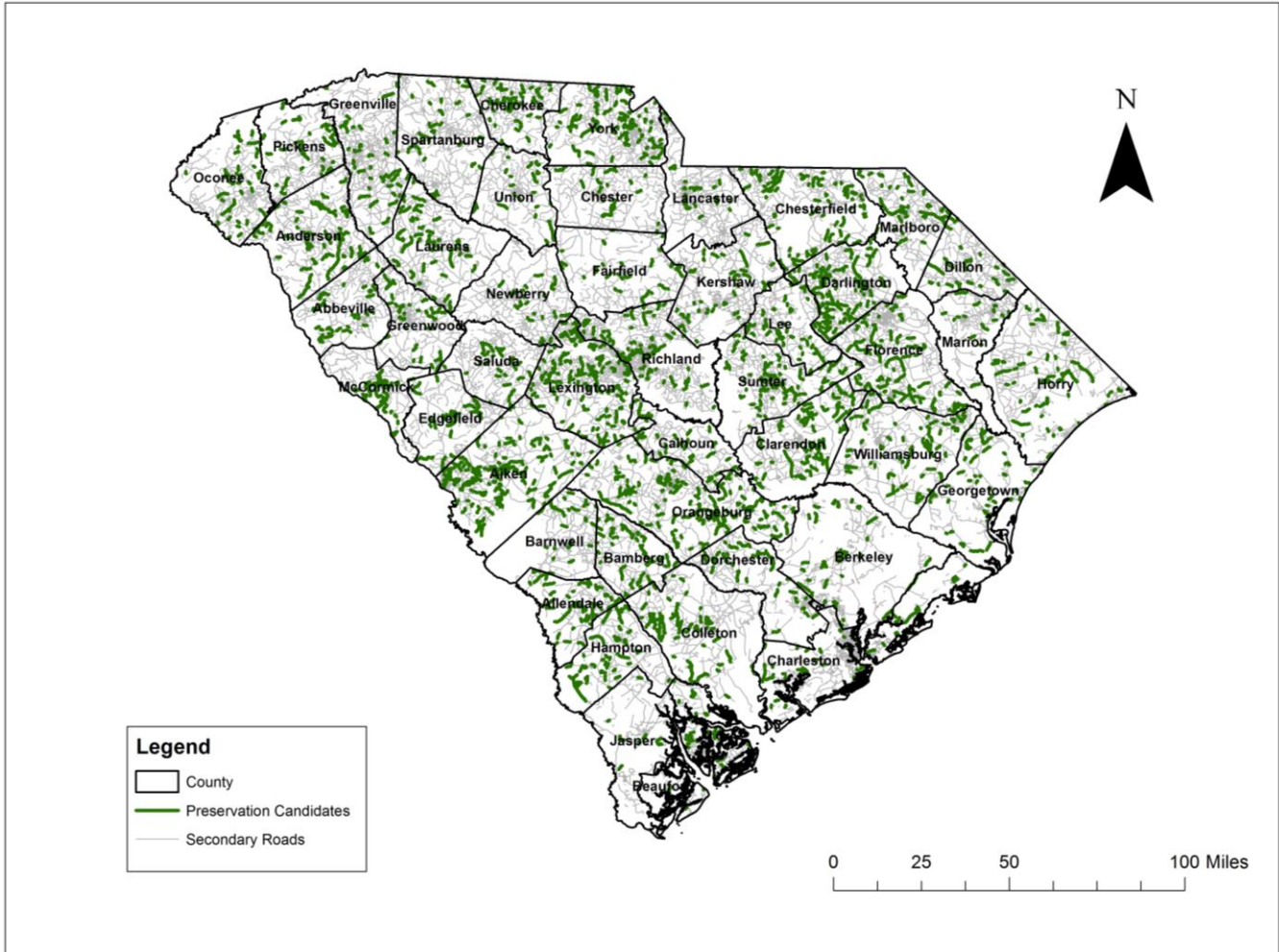


Figure 4.4: Secondary Non-Federal Aid Candidates (100% Consecutive)

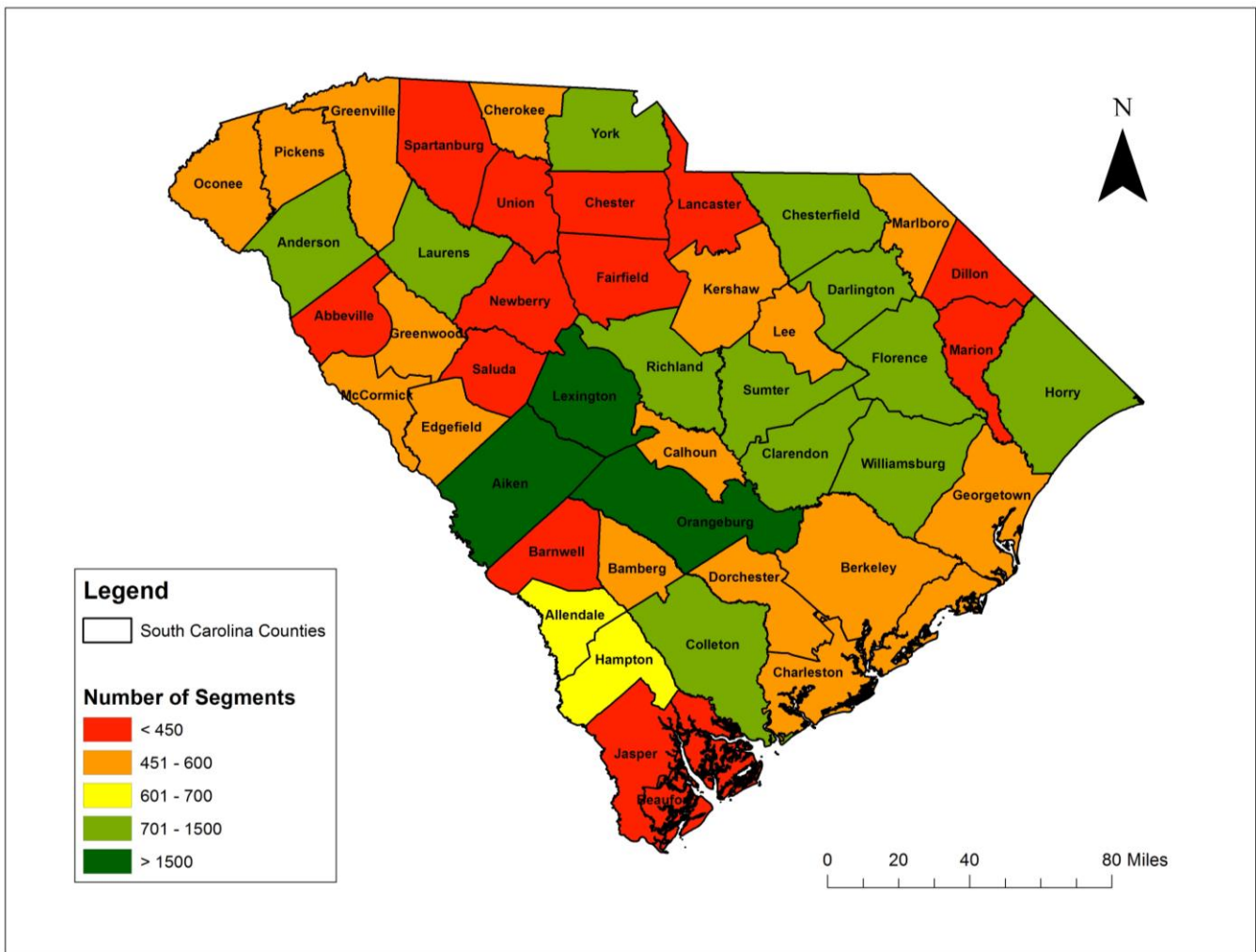


Figure 4.5: Candidate Distribution by County (100% Consecutive)

Figure 4.5 above portrays a color coded map showing the counties in South Carolina.

The counties with the highest number of candidates were Aiken, Lexington, and Orangeburg. Each of these counties has over 1,500 candidate segments within the county.

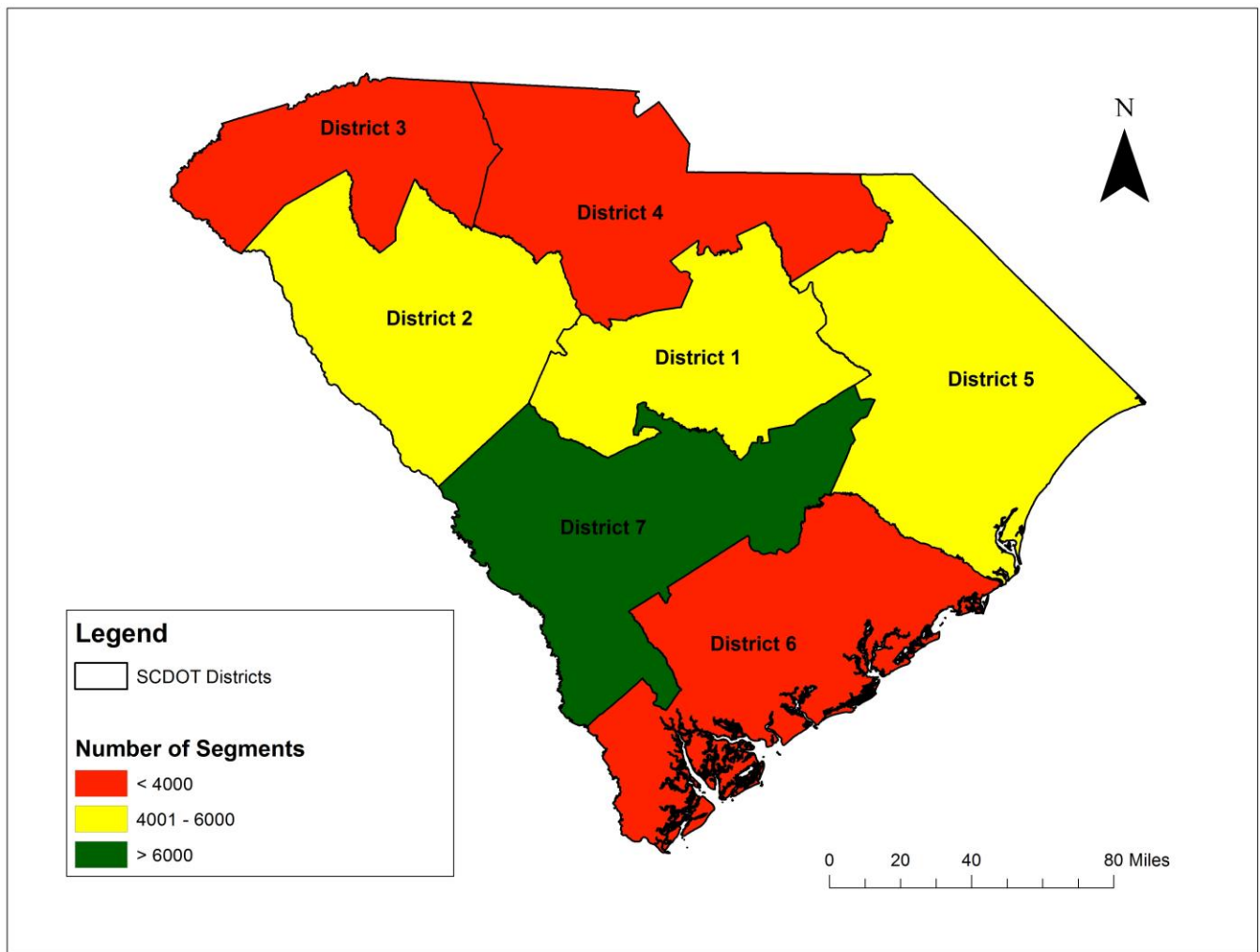


Figure 4.6: Candidate Distribution by District (100% Consecutive)

Figure 4.6 above shows seven districts for the state and their number of candidates.

District 7 shows the most preservation candidates with over 6,000 candidate segments.

This result is not surprising as this district contains two of the three counties with the greatest number of candidates. District 7 contains Aiken, Orangeburg, and Clarendon counties which rank 2nd, 1st, and 6th in number of preservation eligible segments in the state, respectively.

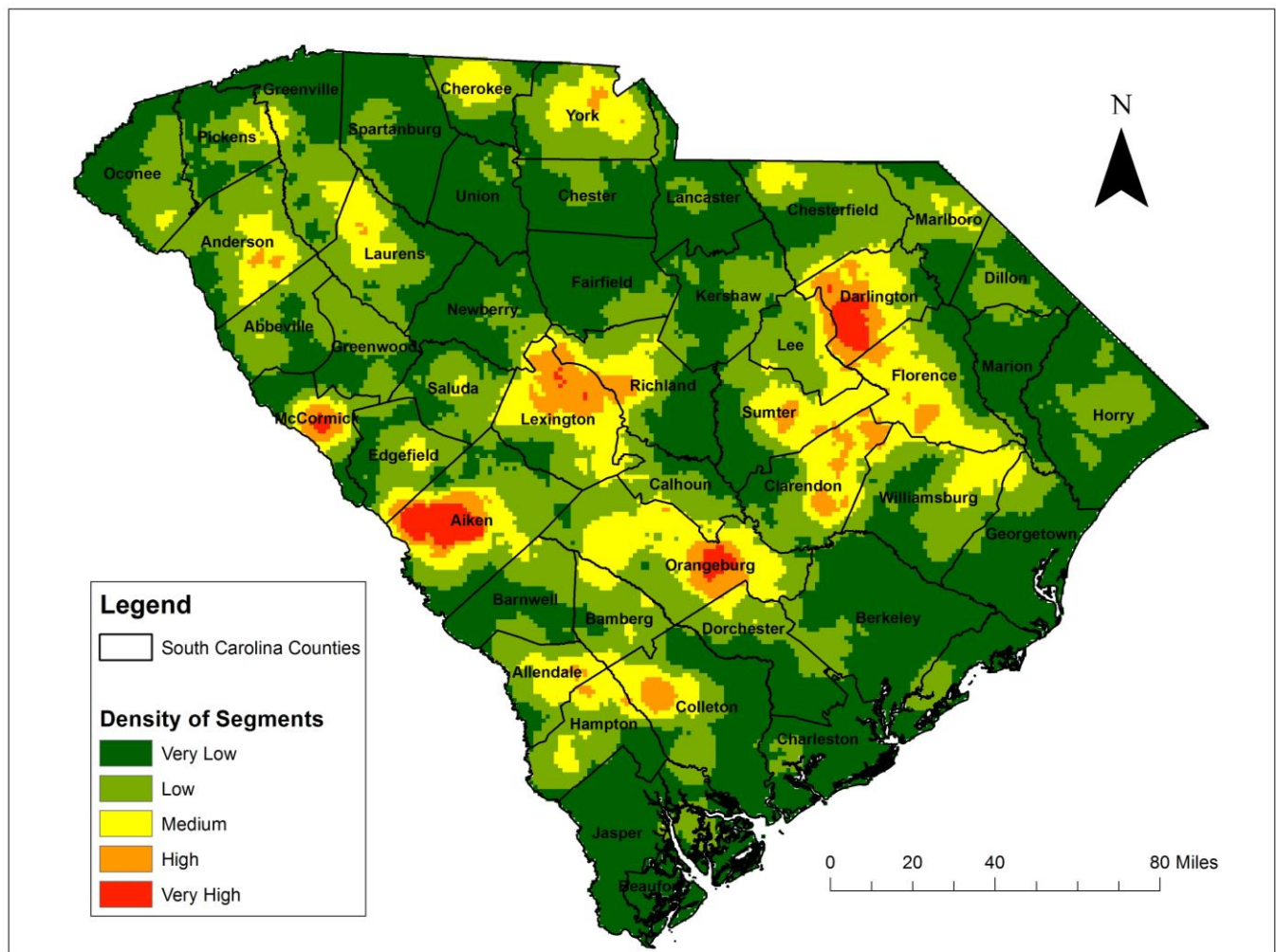
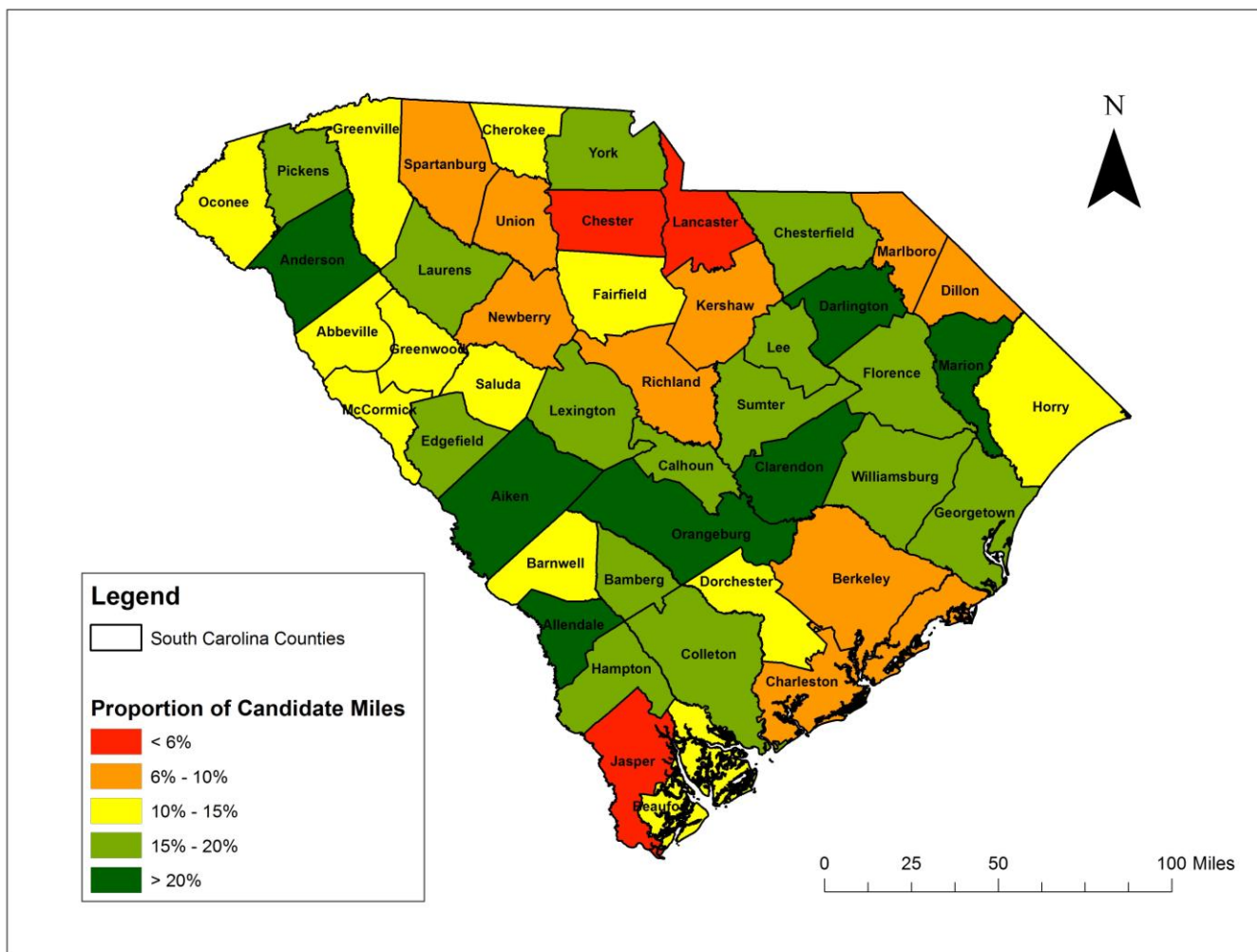


Figure 4.7: Density of Candidates (100% Consecutive)

Figure 4.7 shows a density map for the state based on number of candidate segments.

Aiken, Orangeburg, and Darlington counties show the highest density of candidates in the state. The result of the density map is expected with Orangeburg, Aiken, and Darlington counties being three of the four counties with the largest number of preservation eligible segments.



**Figure 4.8: Proportion of Total Miles Qualified as Candidates by County
(100% Consecutive)**

Figure 4.8 above displays the proportion of total miles in each county that met the qualifications to be pavement preservation candidates. Aiken, Orangeburg, and Clarendon counties all have over 20% of their secondary roadway miles as candidate miles. This result could be expected as these counties had large number of candidate segments. In contrast, Marion County had less than 450 candidate segments but that number still consisted of over 20% of the secondary roadway miles in the county.

80% Consecutive Segment Preservation Candidates

Another analysis was conducted to find the number of segments that would be preservation candidates if only 80% of the consecutive segments met the 3.0 PQI thresholds. This analysis found 39,648 segments that would be preservation candidates. These segments would represent approximately 3869.5 miles of roadway in the state. The average PQI represented in these candidates was 3.46. In contrast, there were 180,199 segments that did not qualify as preservation candidates. These segments totaled up to approximately 16,748.2 miles of roadway. Table 4.2 below portrays the breakdown of the preservation candidates and non-candidates by county.

Table 4.2: Candidates by County (80% Consecutive)

County Name	Number of Candidate Segments (80% Consecutive)	Length of Candidate Segments (80% Consecutive) (miles)	Average Predicted PQI for Candidate Segments (80% Consecutive)	Non-Candidate Segments (80% Consecutive)	Non-Candidate Segment Length (80% Consecutive) (miles)	Non-Candidate Average Predicted PQI (80% Consecutive)
Abbeville	652	64.11	3.33	2886	272.674	2.50
Aiken	2407	232.145	3.45	5678	511.053	2.35
Allendale	946	93.279	3.32	2083	195.857	2.14
Anderson	1169	114.197	3.73	3685	340.809	2.33
Bamberg	748	73.22	3.37	2347	220.97	1.99
Barnwell	393	37.95	3.52	2731	250.56	2.50
Beaufort	485	46.94	3.23	2368	213.98	2.11
Berkeley	676	66.157	3.52	5071	467.37	2.20
Calhoun	579	56.49	3.86	2497	239.16	2.19
Charleston	686	67.15	3.54	6253	552.334	2.15
Cherokee	730	70.9	3.31	3652	347.084	2.40
Chester	359	34.94	3.60	4813	452.37	2.23
Chesterfield	1325	129.13	3.33	4493	422.05	1.83
Clarendon	1324	130.21	3.57	2916	271.63	2.47
Colleton	1280	125.77	3.38	4841	458.17	2.37
Darlington	1708	167	3.38	4240	385.42	2.34
Dillon	437	42.96	3.39	3954	374.48	2.34
Dorchester	702	68.51	3.27	3038	282.03	2.02
Edgefield	573	55.67	3.75	2586	244.11	2.33
Fairfield	432	42.34	3.31	3050	290.95	2.28
Florence	1582	155.16	3.35	5722	525.39	2.42
Georgetown	716	69.45	3.39	2873	263.8	2.05
Greenville	678	66.19	3.45	4475	419.288	2.24
Greenwood	567	55.12	3.75	2886	268.38	2.39
Hampton	857	83.48	3.49	2569	239.58	2.38
Horry	949	92.95	3.55	4762	444.899	2.22
Jasper	135	13.16	3.33	2299	217.84	2.31
Kershaw	614	59.74	3.60	5472	517.8	2.14
Lancaster	301	29.42	3.66	3926	366.2	1.81
Laurens	935	90.7	3.67	4387	409.39	2.39
Lee	679	66.4	3.31	2200	206.07	1.93
Lexington	2096	204.798	3.31	6297	573.374	2.46
Marion	645	63.06	3.60	2311	218.15	2.09
Marlboro	239	23.29	3.50	2839	259.544	2.41
McCormick	665	65.24	3.68	4061	384.82	1.50
Newberry	325	31.16	3.84	4085	383.72	2.26
Oconee	592	57.95	3.34	3596	341.117	2.33
Orangeburg	2591	253.29	3.36	6772	626.207	2.21
Pickens	585	57.15	3.56	1947	185.98	2.42
Richland	1107	106.351	3.59	8041	721.508	2.27
Saluda	507	49.89	3.68	3093	294.64	2.19
Spartanburg	500	48.88	3.40	4648	438.649	2.16
Sumter	1245	121.7	3.38	4688	426.94	2.12
Union	382	37.5	3.67	2896	273.55	2.47
Williamsburg	1182	115.84	3.39	4398	417.83	1.69
York	1363	132.56	3.53	5774	530.472	2.32
TOTAL	39648	3869.497	3.46	180199	16748.199	2.22

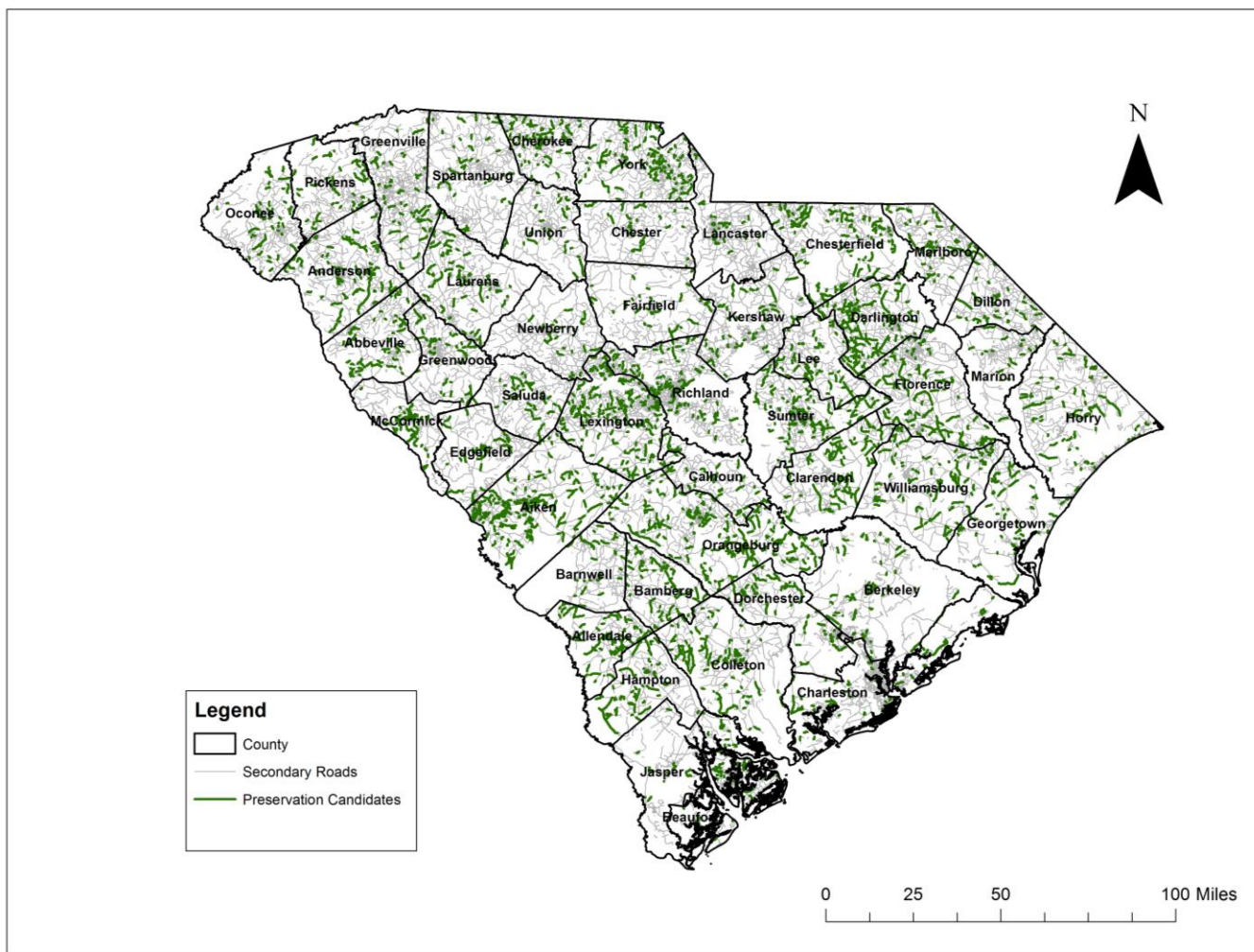


Figure 4.9: Secondary Non-Federal Aid Candidates (80% Consecutive)

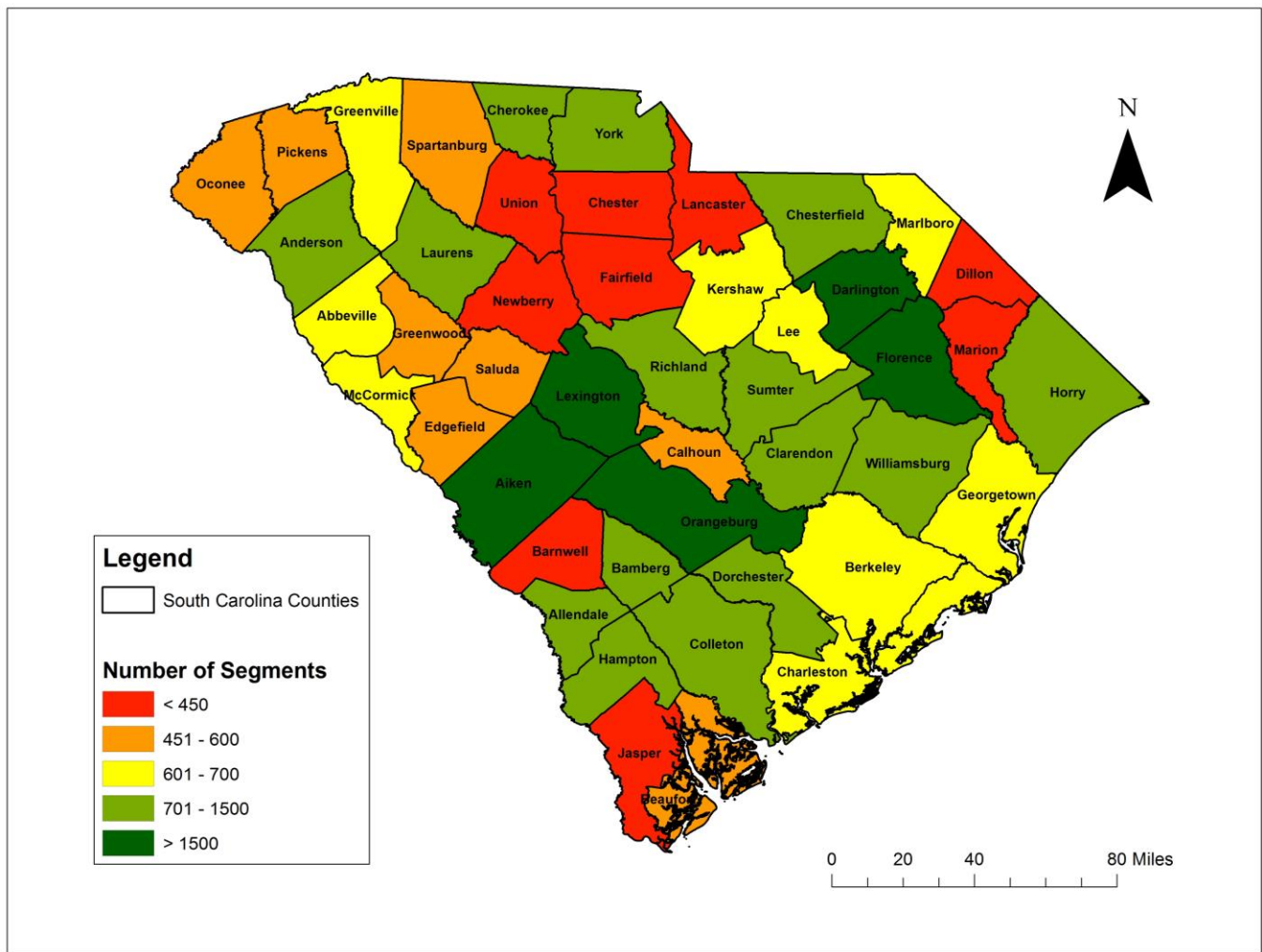


Figure 4.10: Candidate Distribution by County (80% Consecutive)

Figure 4.9 above provides a map view of the preservation candidates for the analysis.

Figure 4.10 displays a color coded map of the counties of South Carolina according to the number of preservation eligible segments in each county. The counties with more than 1,500 segments in each county were Aiken, Lexington, Orangeburg, Florence, and Darlington.

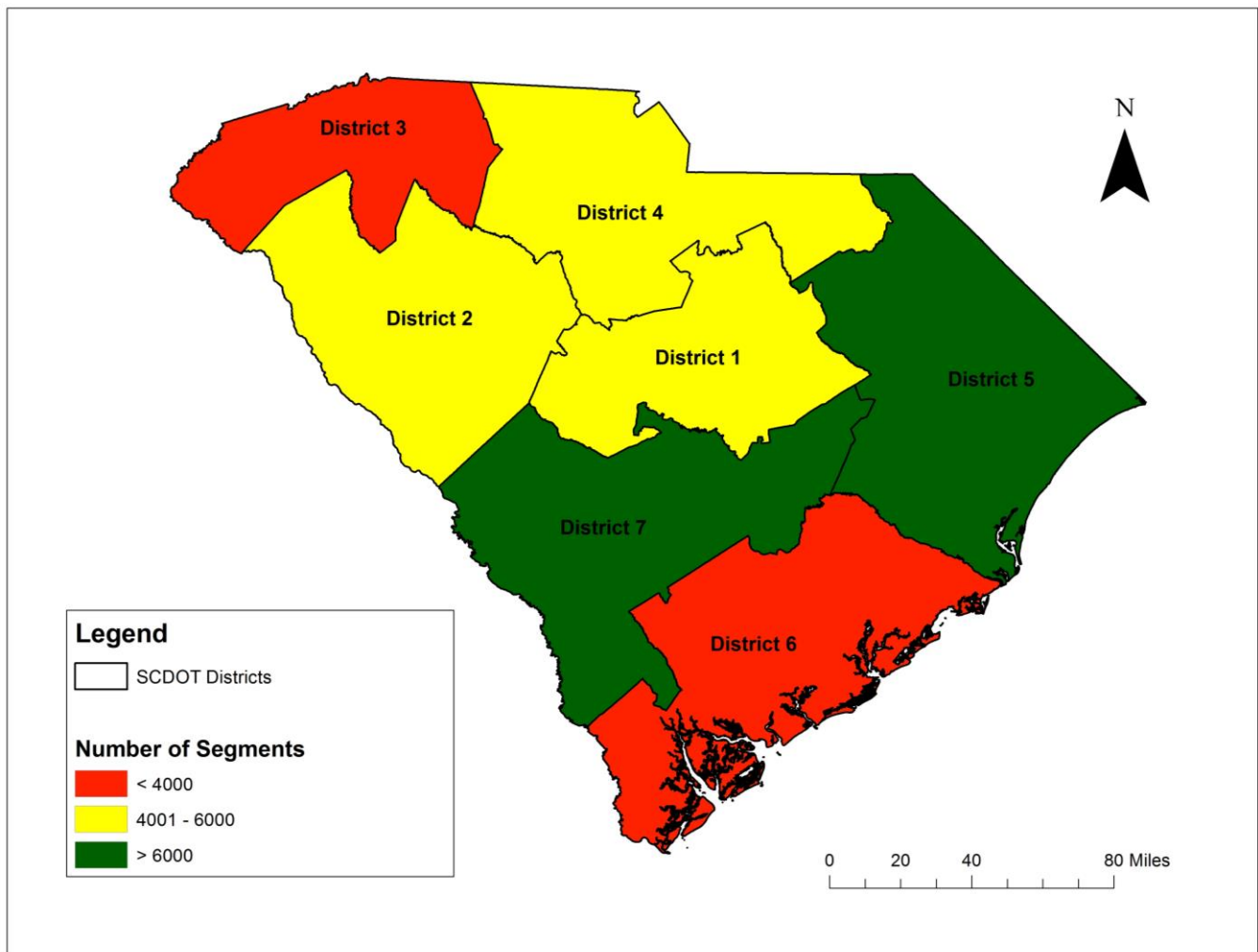


Figure 4.11: Candidate Distribution by District (80% Consecutive)

Figure 4.11 displays the districts for SCDOT color coded according to the number of pavement preservation candidate segments in each. District 5 and 7 are the top two districts with each containing over 6,000 preservation eligible segments. This result would be expected as these two districts contain the top 5 counties with the most preservation eligible segments.

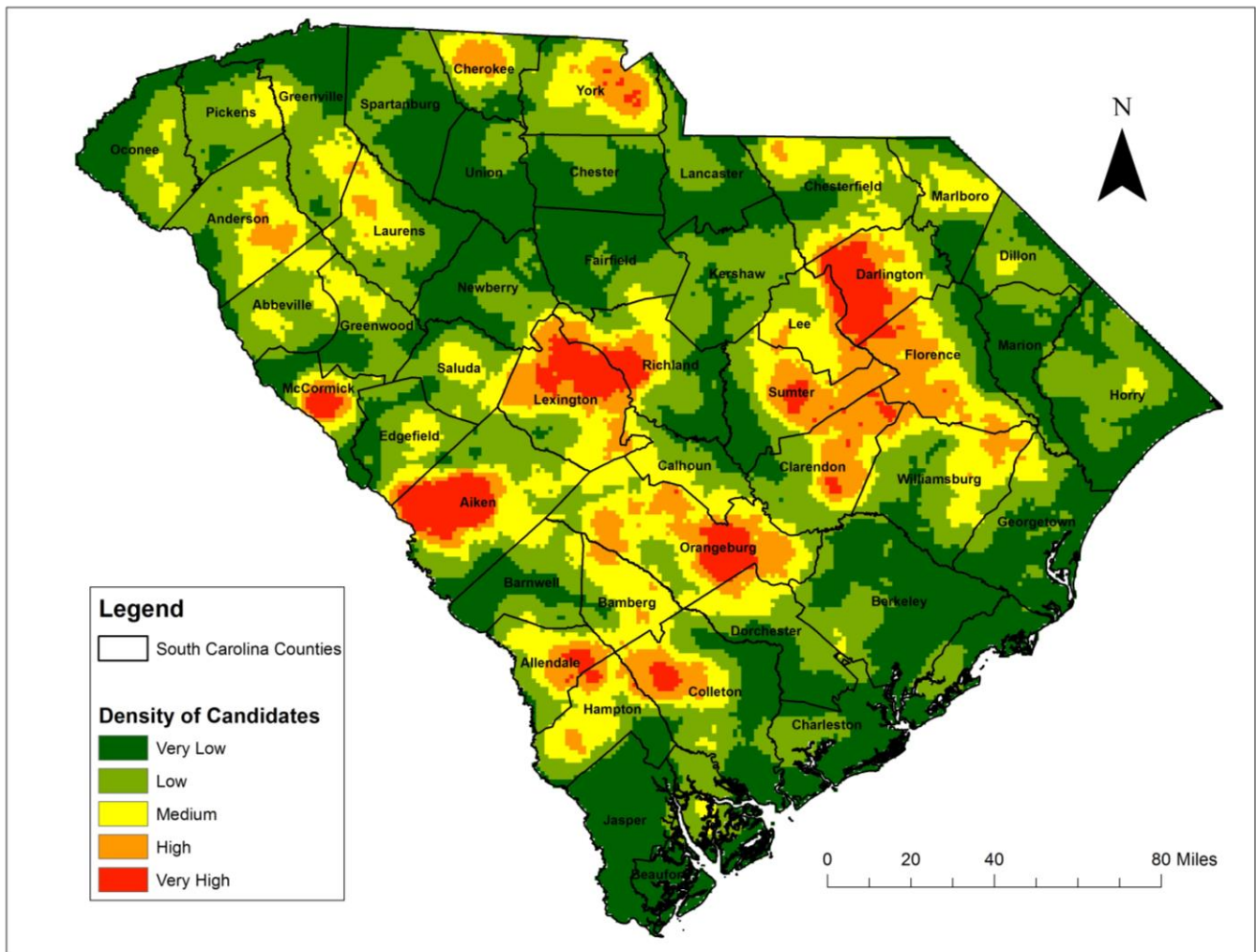
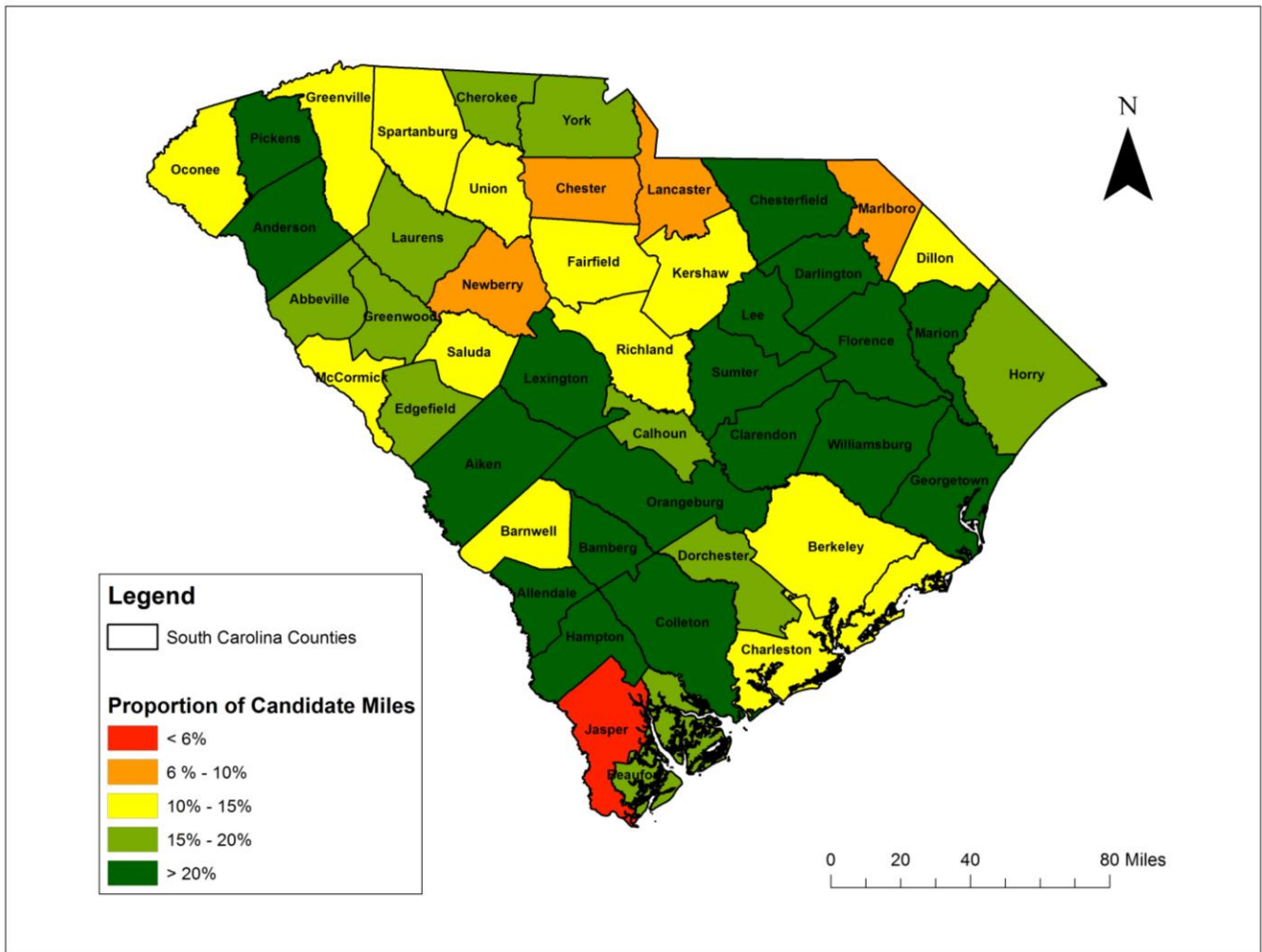


Figure 4.12: Density of Candidates (80% Consecutive)

Figure 4.12 displays a density map created based on the number of preservation candidate segments in the area. The pockets of highest concentration seem to occur in the counties with the most eligible segments like Aiken, Orangeburg, and Darlington. This map also shows a higher concentration in the Columbia area.



**Figure 4.13: Proportion of Total Miles Qualified as Candidates by County
(80% Consecutive)**

Figure 4.13 above displays the proportion of total miles that are qualified as pavement preservation candidates by county. There are a number of counties that have over 20% of their secondary roadway miles qualified as candidate segments after the 80% consecutive analysis.

Comparison of 100% and 80% Consecutive Segments

Two different analyses were conducted to compare 80% candidate versus 100% candidate sites. Table 4.3 below shows a summary of the data discovered from each analysis.

Table 4.3: Summary Data for 100% and 80% Consecutive Analysis

Percent of Segments Consecutive	Number of Candidate Segments	Length of Candidate Segments (miles)	Average Predicted PQI for Candidate Segments	Non-Candidate Segments	Non-Candidate Segment Length (miles)	Non-Candidate Average Predicted PQI
100	30615	3005.057	3.60	189232	17612.639	2.26
80	39648	3869.497	3.46	180199	16748.199	2.22

The 80% consecutive segment analysis provided 9,033 more preservation eligible segments than the 100% consecutive segment analysis. This difference led to 864.44 more miles of roadway eligible for preservation techniques. The average PQI of candidates is lower for the 80% consecutive segment as would be expected because some of segments included in this analysis would have a PQI lower than the PQI needed to be eligible for pavement preservation. Figures 4.14, 4.15, 4.16, 4.17, and 4.18 display the comparison between the 100% and 80% consecutive analyses for both counties and districts in the state. The maps labeled “A” in each figure display the 100% consecutive analysis results while the maps labeled “B” in each figure display 80% consecutive analysis results. Figure 4.16 and Figure 4.17 portray the results of the proportion of total miles that are preservation candidates in each county or district. Figure 4.18 displays the comparison of the density of candidates throughout the state.

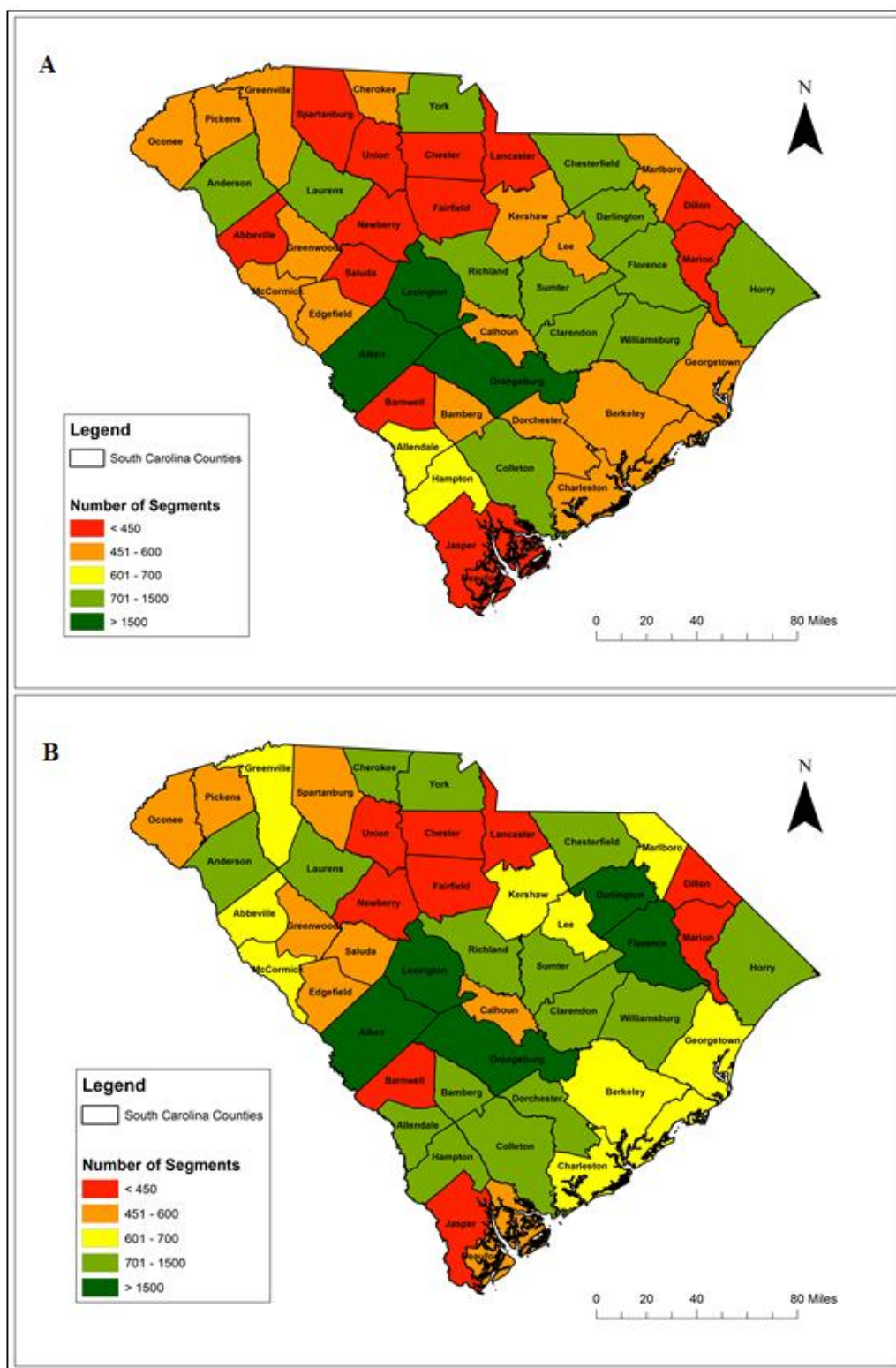


Figure 4.14: Comparison of Number of Candidate Segments by County

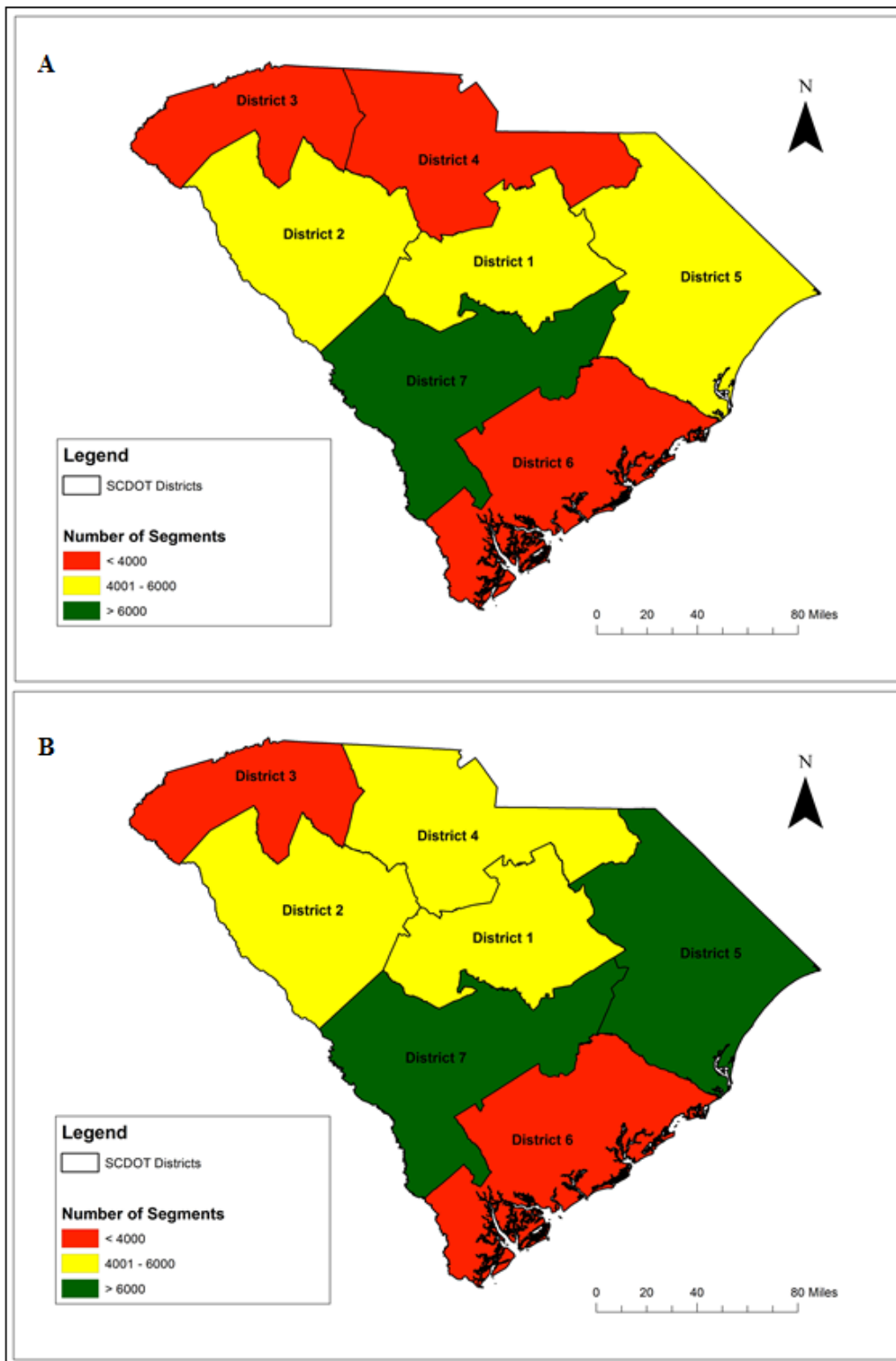


Figure 4.15: Comparison of Number of Candidate Segments by District

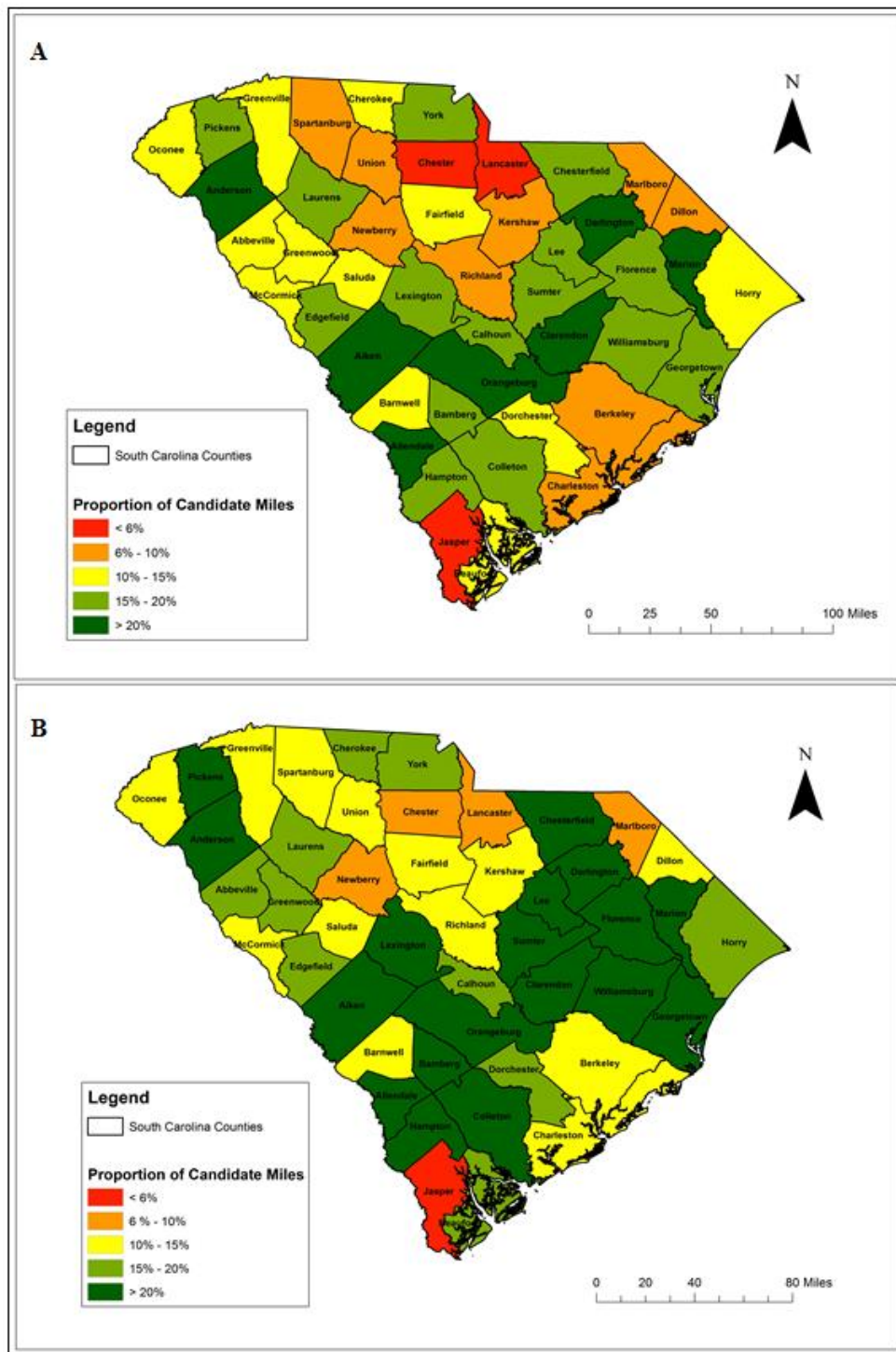


Figure 4.16: Comparison of Proportion of Total Miles Qualified as Candidates by County

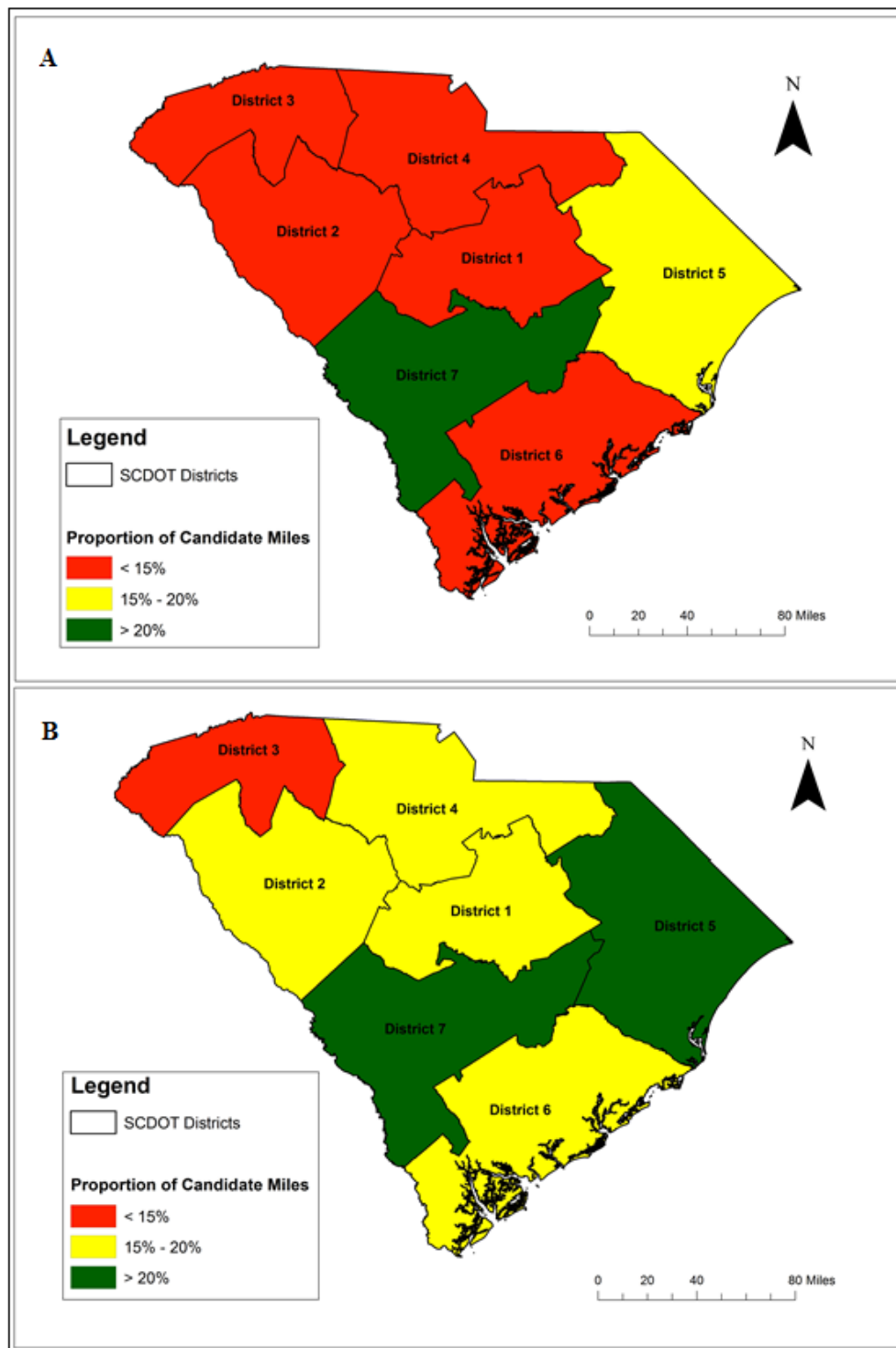


Figure 4.17: Comparison of Proportion of Total Miles Qualified as Candidates by District

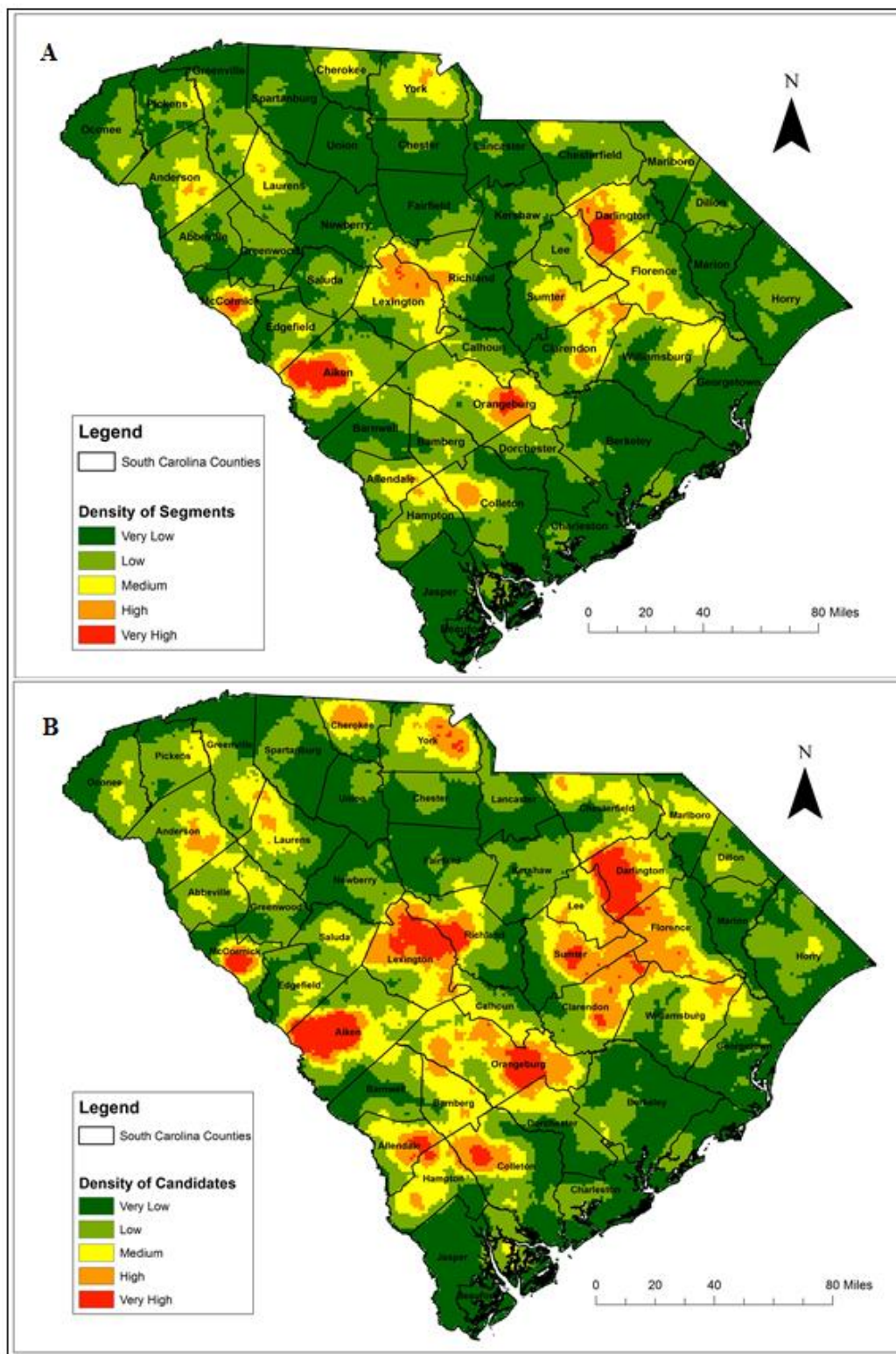


Figure 4.18: Comparison of Candidate Density Statewide

Treatment Tracking Program

Analyzing the current SCDOT ITMS data elements provided an idea of the current data collected by SCDOT. Some of the data elements already collected by the SCDOT include:

- County
- Route Type
- Route Number
- Auxiliary
- Direction
- Begin Mile Point
- End Mile Point
- Length
- AADT
- % Truck Traffic
- Most Recent IRI
- Predicted IRI
- Most Recent PQI
- Predicted PQI
- Most Recent Year of Distress Collection
- % Low, Moderate, and High Severity for Fatigue, Transverse, and Longitudinal Cracking
- % Low, Moderate, and High Severity Raveling

- Low, Moderate, and High Severity Tran Crack Length
- % Low, Moderate, and High Severity Patching
- Maintenance Activity and Year
- Rehab Activity and Year
- Rehab Year
- Pavement Type
- Functional Class

As discussed in Chapter 2, the SCDOT uses a formula to calculate the pavement quality index (PQI) of a roadway to find its condition. This formula was developed by Stantec specifically for the SCDOT. The pavement serviceability index (PSI) is based on the IRI collected by a vehicle in the field. The SCDOT collects the distress data for each distress defined in *Guidelines for Selecting Preventive Maintenance Treatments for Asphalt Treatments*. The collected distress data is used to create a deduct value used in calculating pavement distress index (PDI). The PSI and PDI are used to calculate the PQI to give the overall pavement condition. The PQI is used as a trigger value to decide on maintenance treatments to the roadways. The SCDOT currently collects all data necessary to compute PQI and identify pavement preservation candidates.

While there is currently the right amount of data for candidate identification, the SCDOT lacks in information to find which treatments are working the best throughout the state. The SCDOT ITMS does now allow for users to query daily work reports (DWR) to see what activity has been completed on a roadway segment. These DWRs can give a detailed look into maintenance activities. The detailed DWRs even give the

project labor cost, equipment cost, material cost, and total cost. This DWR query feature in the ITMS gives a good starting point to creating a successful treatment tracking program for pavement preservation in South Carolina. The DWRs are currently only conducted for internal SCDOT work. In addition to DWRs, similar reports would be needed for contracted pavement work. The treatment tracking program should collect the following data:

- Location of the treatment
- Treatment type
- Treatment description
- Volume of treatment implemented
- Cost breakdown of treatment
- Date of treatment (Month/Year)
- Contractor name

To better implement the different treatments throughout the state, collecting data on their actual performance in the field is crucial. Knowledge on the location of the treatment implementation is important as certain treatments may be more successful in some parts of the state in comparison with other parts. County name, route type, route number, beginning mile point, ending mile point, direction, length, and AADT are all data elements needed to identify the location of the treatment. Treatment type and treatment description are needed for obvious reasons. The volume of the treatment applied is also necessary to give an accurate picture of treatment performance. The cost breakdown of the treatment, such as labor cost, equipment cost, and material cost, is important to

display the cost effectiveness of implementing certain treatments. The date of treatment implementation is also important to accurately show the performance of the treatment. Weather as well as the season the treatment was applied in could affect the overall performance of the treatment and show a treatment as ineffective. The name of the contractor or work performing group should also be included. This data could have two advantages: allowing better distribution of work by location and identifying if any one contractor is not performing work up to standard repeatedly.

CHAPTER 5

CONCLUSIONS

Pavement preservation techniques provide the opportunity for state department of transportations around the country to use their budgets wisely to keep the greatest number of roadways at an acceptable condition.

Currently, the South Carolina Department of Transportation does not have a pavement preservation component that is part of their ITMS used for other network information. From surveying those involved in pavement maintenance throughout the state, it became clear that the procedure for implementing pavement preservation needs to improve. The first step to being able to implement such changes was to assess the current practices by the SCDOT through the survey and investigation of the SCDOT ITMS. Comparing SCDOT current practices to other states with established pavement preservation programs revealed that the distress identification and treatment options in the South Carolina are comparable to other states. After looking at existing pavement software packages, it became clear the SCDOT was lacking in its ability to predict future pavement condition, identify which treatments to implement, and accurately budget for those treatments.

For the SCDOT to have the improved abilities to implement pavement preservation, this research developed a process to identify the candidates for preservation from current SCDOT data. Identifying the candidates allows the SCDOT to get a pool of candidates that can be treated.

Once the candidates have been treated, collecting data on the same segments is important to see how the treatments are actually reacting in the field. This research gives an outline for the data that should be collected for these segments. This information allows the SCDOT to compare treatment actual performance to the expected performance. Learning which treatments react the best in certain locations in the state can allow for better treatment implementation. This system can help the SCDOT prevent implementing a technique that will not lead to good results.

The practices outlined in this research are designed with the South Carolina Department of Transportation current practices in mind. This system should allow for an improved use of funds to keep South Carolina roadways at a better level.

APPENDICES

Appendix A

Pavement Software Comparison Matrix

KEY

R = Required

O = Optional

	SCDOT	Streetsaver	OPTime	PAVER 7.0
Route Information				
Route ID	R	R		R
Length	R	R		R
Width		R		R
Area		R		R
Begin Point	R	R		
End Point	R	R		
Number of Lanes		R		O
Shoulder Information		O		O
ADT	R	O	R	
% Truck Traffic	R			
Functional Class	R	R		
Pavement Characteristics				
Surface Type	R	R	R	R
Concrete Specific		O		O
Initial Construction Date		R		R
Inspection Date	R	R		R
Distress Type	R	R	R	R
Distress Severity	R	R		R
Distress Quantity	R	R	R	R
Maintenance Data				
Treatment Date	R	R	R	R
Treatment Type	R	R	R	R
Treatment Cost				
Rehabilitation Data				
Rehab Date	R	R		
Rehab Activity	R		R	
Rehab Cost		R	R	

Budget/Other Cost Needs				
Interest/Inflation Rate		R	R	R
Budget Start Date		R		R
Budget Length		R		R
User Delay Cost			O	

Table A-1: Comparison Matrix for Pavement Software Packages

Appendix B

SCDOT Pavement Management Survey

SCDOT Pavement Management Survey	
<p>1. Please provide your contact information.</p> <p>Name: <input type="text"/></p> <p>Email Address: <input type="text"/></p> <p>Phone Number: <input type="text"/></p> <p>2. What is your position?</p> <p><input type="radio"/> DME</p> <p><input type="radio"/> RME</p> <p><input type="radio"/> RCE</p> <p>Other (please specify)</p> <p><input type="text"/></p> <p>3. How many years of experience do you have with pavement maintenance and preservation?</p> <p><input type="radio"/> 0-2</p> <p><input type="radio"/> 3-5</p> <p><input type="radio"/> 6-10</p> <p><input type="radio"/> 11-15</p> <p><input type="radio"/> 16-20</p> <p><input type="radio"/> 20+</p> <p>4. What process do you use to identify preservation candidates in your area? (e.g., run query in SCDOT data system, or use report generated by district office)</p> <p><input type="text"/></p>	

5. Does your area conduct pavement evaluations to supplement the data collected by the van (interstates every year, non-interstate on 3-5 year rotation)? For example, do you have a RME or other doing pavement evaluations to select candidates for preservation?

- ☐ Yes
- ☐ Sometimes
- ☐ No

SCDOT Pavement Management Survey

6. Do you have a written process for these evaluations?

☐ Yes

☐ No

7. Do you maintain a separate database?

☐ Yes

☐ No

Other (please specify)

8. What is the frequency of these evaluations?

9. What is the coverage of these evaluations? Mileage per year? or route category?

SCDOT Pavement Management Survey

10. What types of pavement preservation treatments have you used in your area?

- ☐ Asphalt Rejuvenators
- ☐ Asphalt Sealers
- ☐ Crack Sealing
- ☐ Crack Filling
- ☐ Scrub Seals
- ☐ Sand Seals
- ☐ Chip Seals
- ☐ Cape Seals
- ☐ Slurry Seals
- ☐ Micro-surfacing
- ☐ Ultra-thin Overlays
- ☐ Bonded Wearing Course
- ☐ Profile Milling
- ☐ Ultra-Thin Overlays (generally $\leq \frac{3}{4}$ inch)
- ☐ Thin Overlays (non-structural, generally $\leq 1\frac{1}{2}$ inch)
- ☐ Mill & Resurface (non-structural, generally $\leq 1\frac{1}{2}$ inch)
- ☐ Full Depth Patch
- ☐ Hot In-place Recycling
- ☐ Cold In-place Recycling

Other (please specify)

11. How do you decide which preservation treatment to use for a roadway?

12. Is there a specific type of treatment that you prefer to use? Why?

13. Are there preservation treatments that you would rather not use? Why?

14. Are there differences in treatment decisions by county in your district?

- ☐ Yes
- ☐ No
- ☐ Don't Know

15. Do you have a specific pot of funds for maintenance (specifically pavement preservation)?

- ☐ Yes
- ☐ Sometimes
- ☐ No

SCDOT Pavement Management Survey

16. What is the typical funding level? How does this get distributed from district level to county level? Are there any specifications on this money?

SCDOT Pavement Management Survey

17. What obstacles do you face with pavement preservation?

18. If a pavement preservation decision support system were developed for SCDOT, would you want that in a stand alone software package or added to the SCDOT RIMS/ITMS data system?

- ☐ Stand-alone
- ☐ SCDOT system

Other (please specify)

19. Do you have any suggestions for improving pavement preservation procedures, decisions, policies?

Thank you for your time to fill out this survey!

Figure B-1: Pavement Management Survey Sent to SCDOT

Appendix C

Matlab Code for Identifying 100% Consecutive Preservation Candidates

```
% Look for consecutively large PQI

% Logan Reed
% 6/9/2015

clear
clc

% Excel file information
FileName = 'Secondary_NonFedAid_Eligible1.xlsx';
Worksheet = 'All';
SaveTo = 'True or False';

% Preliminary work
% Load the worksheet
[Num,Txt,Data] = xlsread(FileName, Worksheet);
% Get the length of the sheet
R = length(Num);

% Write falses
for t = 3:R+1
    Data{t,41} = 'False';
end

% Increment the rows
i = 1;
for step = i:R-4
    Headers = step+2;
    % Check for the conditions
    % Check for 5 cells in a row that are greater
    if Num(step,14) >= 3.0 && ...
        Num(step+1,14) >= 3.0 && ...
        Num(step+2,14) >= 3.0 && ...
        Num(step+3,14) >= 3.0 && ...
        Num(step+4,14) >= 3.0
        %Check to make sure county is the same
        if Num(step,1) == Num(step+1,1) && ...
            Num(step,1) == Num(step+2,1) && ...
            Num(step,1) == Num(step+3,1) && ...
            Num(step,1) == Num(step+4,1)
            %Check to make sure the route numbers are the same
            if Num(step,3) == Num(step+1,3) && ...
                Num(step,3) == Num(step+2,3) && ...
                Num(step,3) == Num(step+3,3) && ...
                Num(step,3) == Num(step+4,3)
                % Check to make sure the route names are the same
                if strcmp(Data(Headers,2),Data(Headers+1,2)) == 1 && ...
                    strcmp(Data(Headers,2),Data(Headers+2,2)) == 1 && ...
                    strcmp(Data(Headers,2),Data(Headers+3,2)) == 1 && ...
                    strcmp(Data(Headers,2),Data(Headers+4,2)) == 1
```

```

% Check to make sure the direction is the same
if strcmp(Data(Headers,5),Data(Headers+1,5)) == 1 && ...
    strcmp(Data(Headers,5),Data(Headers+2,5)) == 1 && ...
    strcmp(Data(Headers,5),Data(Headers+3,5)) == 1 && ...
    strcmp(Data(Headers,5),Data(Headers+4,5)) == 1
    Data{Headers,41} = 'True';
    Data{Headers+1,41} = 'True';
    Data{Headers+2,41} = 'True';
    Data{Headers+3,41} = 'True';
    Data{Headers+4,41} = 'True';
end
end
end
end
end
end

% Save the Data in a new worksheet
xlswrite(FileName, Data, SaveTo);

```

Figure C-1: Matlab Code for 100% Consecutive Segment Identification

Appendix D

Matlab Code for Identifying 80% Consecutive Preservation Candidates

```
function [Binary] = TrueFalse(Cell)
% Return a 1 if Cell is greater than or equal to 3.0
% Return a 0 if Cell is below 3.0

if Cell >= 3.0
    Binary = 1;
else
    Binary = 0;
end
```

Figure D-1: True-False MATLAB Code

```

% 80% consecutive PQI

% Logan Reed
% 6/10/15

clear
clc

% Excel file information
FileName = 'Secondary_NonFedAid.xlsx';
Worksheet = 'All';
SaveTo = 'True or False';

% Preliminary work
% Load the worksheet
[Num,Txt,Data] = xlsread(FileName, Worksheet);
% Get the length of the sheet
R = length(Num);

% Write falses
for t = 3:R+1
    Data{t,42} = 'False';
end

% Increment the rows
i = 1;
for step = i:R-4
    Headers = step+2;
    % Check for the conditions
    % Check for 5 cells in a row that are greater
    if TrueFalse(Num(step,14)) + ...
        TrueFalse(Num(step+1,14)) + ...
        TrueFalse(Num(step+2,14)) + ...
        TrueFalse(Num(step+3,14)) + ...
        TrueFalse(Num(step+4,14)) > 3
        % Check if the same county
        if Num(step,1) == Num(step+1,1) && ...
            Num(step,1) == Num(step+2,1) && ...
            Num(step,1) == Num(step+3,1) && ...
            Num(step,1) == Num(step+4,1)
            % Check to make sure the route numbers are the same
            if Num(step,3) == Num(step+1,3) && ...
                Num(step,3) == Num(step+2,3) && ...
                Num(step,3) == Num(step+3,3) && ...
                Num(step,3) == Num(step+4,3)
                % Check to make sure the route names are the same
                if strcmp(Data(Headers,2),Data(Headers+1,2)) == 1 && ...
                    strcmp(Data(Headers,2),Data(Headers+2,2)) == 1 && ...
                    strcmp(Data(Headers,2),Data(Headers+3,2)) == 1 && ...
                    strcmp(Data(Headers,2),Data(Headers+4,2)) == 1

```

```

% Check to make sure the direction is the same
if strcmp(Data(Headers,5),Data(Headers+1,5)) == 1 && ...
    strcmp(Data(Headers,5),Data(Headers+2,5)) == 1 && ...
    strcmp(Data(Headers,5),Data(Headers+3,5)) == 1 && ...
    strcmp(Data(Headers,5),Data(Headers+4,5)) == 1
    Data{Headers,42} = 'True';
    Data{Headers+1,42} = 'True';
    Data{Headers+2,42} = 'True';
    Data{Headers+3,42} = 'True';
    Data{Headers+4,42} = 'True';
end
end
end
end
end
end

% Save the Data in a new worksheet
xlswrite(FileName, Data, SaveTo);

```

Figure D-2: Matlab Code for 80% Consecutive Segment Identification

Appendix E

Data Elements for Treatment Tracking Program

Data Elements	Description	Type of Data	Example
Location			
County	County where work is completed	County name or code	Abbeville (1)
Route Type	Route type for roadway where treatment is implemented	Route type symbol	S-
Route Number	Route number for roadway where treatment is implemented	Number	43
Begin Mile Point	Beginning mile point for section where treatment is implemented	Number	0.4
End Mile Point	Ending mile point for section where treatment is implemented	Number	0.5
Length	Length of section where treatment is implemented	Number	0.1
Direction	Direction of section where treatment is implemented	Direction	E
Treatment Information			
Treatment Type	Treatment implemented in the field	Treatment name or code	Crack Sealing, Chip Seals, Microsurfacing, Ultra Thin Asphalt Overlays, Full Depth Patch
Treatment Quantity	Amount of treatment implemented (volume)	Number	1
Treatment Description	Brief description of work completed	Short word set	Patching/Minor Leveling
Treatment Date	Date treatment is implemented	Month/Day/Year	4/10/2014
Contractor Name	Name of contractor that implemented treatment	Short word set	Crowder Construction Company
Cost Information			
Labor Cost	Cost of labor on project	Number	2352
Unit Cost of Treatment	Unit cost of the treatment implemented	Number	35
Material Cost	Cost of materials on project	Number	55
Total Cost	Total cost of the treatment project	Number	4000

Figure E-1: Data Elements for Treatment Tracking

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